BIG CREEK REGION CONSERVATION REPORT

WATER

ONTARIO DEPARTMENT OF PLANNING AND DEVELOPMENT

CONSERVATION BRANCH

BIG CREEK REGION

CONSERVATION REPORT

WATER

1958

AUTHORSHIP

The field work and preparation of the Water Section of the Big Creek Region Conservation Report was done under the supervision of C.E. Bush assisted by J.W. Murray and G.S. Bartlett.

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Our thanks are also extended to Mr. R.F. Quance and the Simcoe Reformer for permission to use the flood photographs which appear following page 13.

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STATED OR IMPLIED IN THIS REPORT

1. That the Big Creek Region Conservation Authority set up an Advisory Committee on Pollution Control. p. 33

2. That the Authority support the present work of the Water Resources Commission of Ontario and the Department of Lands and Forests in Pollution Control by publicizing the present conditions and the need for co-operation by every individual and industrial company. p. 33

3. That the Authority establish ground water observation wells for the study of the North Creek water table fluctuations. p. 45

4. That the Authority encourage the dissemination of irrigation "know-how" among the farmers concerned. p. 46

5. That the Authority assist in the proper location and construction of farm ponds. p. 46

6. That the Authority give early consideration to the construction of a dam on North Creek. p. 46

7. That the Authority consider using The Conservation Authorities Act to prevent selfish and indiscriminate use of stream flow. p. 47

8. That the Authority investigate the construction of reservoirs as a conservation measure. p. 49

9. That the Authority purchase, as soon as possible, the necessary land required for the postponed construction of reservoirs, thereby avoiding the high land prices of the future. p. 50

10. That the Authority construct a series of Community Ponds throughout the Watershed. p. 61

CHAPTER 1

GENERAL DESCRIPTION OF THE WATERSHED

1. Boundary and Dimensions

The Big Creek Region Conservation Authority covers an irregular-shaped area of 610.2 square miles located on the north shore of Lake Erie at Long Point Bay. The area extends northward from the lake for a maximum distance of 36 miles and has a maximum width of about 28 miles along an east-west line through the towns of Simcoe and Delhi.

The area is bounded on the west by the Otter Creek watershed; on the north by watersheds of the South Branch of the Thames River and the Whiteman and MacKenzie Creek areas of the Grand River system; on the east by the Sandusk Creek drainage area and on the south by Lake Erie. It has an overall lakeshore length of 39.5 miles including Turkey Point but not Long Point or the five mile-long marsh area immediately west of Long Point.

The area is comprised of a number of smaller drainage basins, the most important being the Big Creek and Lynn River basins and those of the Clear, Dedrich, Young and the Nanticoke Creeks. In addition there are eleven unnamed minor creeks draining directly into Lake Erie which for the purpose of this report have been grouped into five areas and referred to by the letters A, B, C, D and E.

The Big Creek and the Lynn River each have several important tributaries as shown in Table 1. A map of the Big Creek Region Watershed is shown in the accompanying Figure 1.

2. Municipalities

The Big Creek Region lies within the counties of Brant, Haldimand, Norfolk and Oxford and consists of all, or parts of, the following townships:


DRAINAGE AREAS
BIG CREEK 281.0 SQ. MI
CLEAR CREEK 26.8
DEDRICH CREEK 32.3
LYNN RIVER 108.8
NANTICOKE CREEK 71.0
YOUNG CREEK 19.4
AREA A. 4.0
AREA B. 11.5
AREA C. 28.4
AREA D. 15.9
AREA E 11.2
TOTAL AREA = 610.3 SQ. MI
HARLEY
NEW DURHAM
TEETERVILLE
WINDHAM CENTRE
WATERFORD
TOWNSEND CENTRE
ROCKFORD
TYRRELL
DELHI
SIMCOE
NANTICOKE
PORT DOVER
PORT ROWAN
ST. WILLIAMS
VENISON
FAIRGROUND
A
B
C
D
E
PLAN OF
BIG CREEK REGION WATERSHED
SHOWING
CONSERVATION RESERVOIRS
LEGEND
RESERVOIR SITES INVESTIGATED
AREA SUBJECT TO FLOODING
4 miles = 1"
FIG. I

County	Township	Percentage
Brant	Burford	40
Haldimand	Walpole	15
Norfolk	Houghton	68
	Middleton	52
	North Walsingham	99 93
	South Walsingham	100
	Townsend	72
	Windham	97
	Charlotteville	100
Oxford	North Norwich	14
	South Norwich	24
	East Oxford	20

The area has a total population of 45,347 with the largest centres being the towns of Simcoe (8,005), Delhi (3,018) and Port Dover (2,722). Other centres in the area include the villages of Waterford (1,863) and Port Rowan (768) and the police villages of Vittoria (439) and St. Williams (165). The above population figures are as of 1957.

3. Terrain

The topography of the Big Creek Region varies, generally, from fairly flat with good drainage to undulating. Geologically, the area is fairly young, with the valleys on all streams being either V-shaped or U-shaped with little or no flood plains.

There are, however, a few exceptions to this generalization which should be mentioned. The topography of the Lynn River area is comparatively rugged with lateral slopes of both the river and its tributaries ranging from 50 to 150 feet to the mile. Another rugged area is found in the vicinity of Waterford, located on the Nanticoke Creek.

There are no natural lakes in the area and only two small marshy areas located at the headwaters of the Nanticoke Creek. The Waterford lakes consisting of a mill-pond and several flooded gravel pits are the largest bodies of water within the area and are a valuable asset to the region from the point of recreation and summer flow. These lakes have a water surface area of about 350 acres.

TABLE 1

DRAINAGE AREAS OF BIG CREEK REGION

River	Tributaries	Drainage Area Square Miles	
BIG CREEK			281.0
	North Creek	20.9	
	Trout Creek	6.2	
	Venison Creek	34.5	
	Brandy Creek	2.9	
	Cranberry Creek	6.8	
LYNN RIVER			108.8
	Patterson Creek	30.9	
	Black Creek	46.7	
CLEAR CREEK			26.8
	East Branch	8.6	
NANTICOKE CREEK			71.0
YOUNG CREEK			19.4
DEDRICH CREEK			32.4
AREA A - 1 small stream in this area			4.0
AREA B - 3 " " " " "			11.5
AREA C - 5 " " " " "			28.4
AREA D - 1 " " " " "			15.9
AREA E - 2 " " " " "			11.2
TOTAL FOR BIG CREEK REGION			610.4

Hydrometric Gauges

Port Rowan		273.3
North Creek		20.9
Walsingham		228.2
Dick's Hill		141.5

Places

Town of Delhi		140.1
" " Simcoe		48.3
" " Port Dover		107.0
Village of Waterford		26.5

The river valleys themselves break the general scene, with those on Big Creek below Delhi reaching 100 feet or more in depth and from a quarter to half a mile in width. These deep, narrow valleys offer many suitable damsites but, due to their low reservoir capacity, do not provide low-cost storage.

The soils of the area are predominantly sand and till plain. Soil types are tabulated for each drainage area as shown in Table 2.

The wooded areas, including plantations, amount to 15 per cent of the Lynn River and Nanticoke Creek drainage areas; 25 per cent of the Clear Creek area and 19.4 per cent of the Big Creek Region.

4. Rivers and Main Tributaries

(a) Big Creek

Big Creek is the largest stream in the region, draining a total of 281.0 square miles, and having a main channel 55.6 miles in length. Altogether there are 13 major tributaries varying from 2.5 to 14.2 miles in length. The total fall is 428 feet, an average of 7.7 feet per mile. The water level profile and gradient tables for Big Creek and its tributaries appear in Figure 2.

The creek rises at a point almost nine miles directly west of the hamlet of Harley; then flows eastward to a point two miles south-east of Harley from which it flows southwards to Lake Erie, passing through Teeterville, Delhi, Walsingham and Port Royal. Its mouth is located in the Inner Bay at a point 1¼ miles south of Port Rowan.

Of its many tributaries North Creek is probably the most important at the present time due to it following a course through tobacco lands where the practice of irrigating is becoming more prevalent.

The water level profiles and gradient tables for the other streams of the Big Creek Region can be found in Figure 3.

TABLE 2

PERMEABILITY OF SOILS IN THE BIG CREEK REGION
PER CENT OF WATERSHEDS

Watershed or Designation of Area (As shown on Table 1)	Pervious		Semi-Pervious		Almost Impervious	
	Sand Plains	Beaches & Shorecliffs	Till Moraine	Till Plains (Drumlinized)	Clay Plains	Bogs and Marshes
BIG CREEK	73	1	17	6	2	1
CLEAR CREEK	97	-	-	-	3	-
DEDRICH CREEK	75	-	-	-	25	-
LYNN RIVER	51	1	3	-	44	1
NANTICOKE CREEK	38	2	14	-	45	1
YOUNG CREEK	63	3	-	-	34	-
AREA "A"	91	9	-	-	-	-
AREA "B"	19	-	-	-	81	-
AREA "C"	59	1	-	-	28	12
AREA "D"	86	-	-	-	14	-
AREA "E"	-	-	-	-	100	-
NORTH CREEK	97	-	3	-	-	-

A small slow-moving tributary in the headlands of the Big Creek.

North Creek — just above its confluence with Big Creek.

The mouth of Big Creek as it empties into Lake Erie.

(b) Lynn River

Lynn River and its numerous tributaries drain 108.8 square miles of the Big Creek Region. Only two tributaries are named on the map, viz., Black Creek, which joins the Lynn River at Port Dover, half a mile up the river from Lake Erie; and Patterson Creek, which extends northwards from the town of Simcoe to its headwaters near the Michigan Central Railway about 1½ miles east of Windham Centre. At one time the entire watercourse from the above-mentioned headwaters, through Simcoe to Lake Erie, was called Patterson Creek. At the present time, however, the river from Simcoe to Lake Erie only is referred to as the Lynn River. Another tributary coming from the west and having its confluence with the Lynn at Simcoe is known locally as Kent Creek. This title, however, is not shown on most present-day maps. The total length of the Lynn River and Patterson Creek is 17.3 miles, with a fall of 225 feet, giving an average gradient of 13.0 feet to the mile.

Black Creek is an important tributary of the Lynn River system draining the whole easterly part of the watershed. It has a total length of 13.2 miles with a fall of 200 feet giving an average gradient of 15.2 feet to the mile.

(c) Dedrich Creek

Dedrich Creek rises about 2 miles east of Silver Hill and flows south to empty into the Inner Bay of Lake Erie a mile south of Port Rowan. It drains the area east of the Big Creek for a distance of 13.7 miles with a fall of 203 feet; averaging 14.8 feet to the mile. There is one major tributary, viz., Mud Creek, which is 8.17 miles long with a gradient of 15.9 feet per mile.

(d) Young Creek

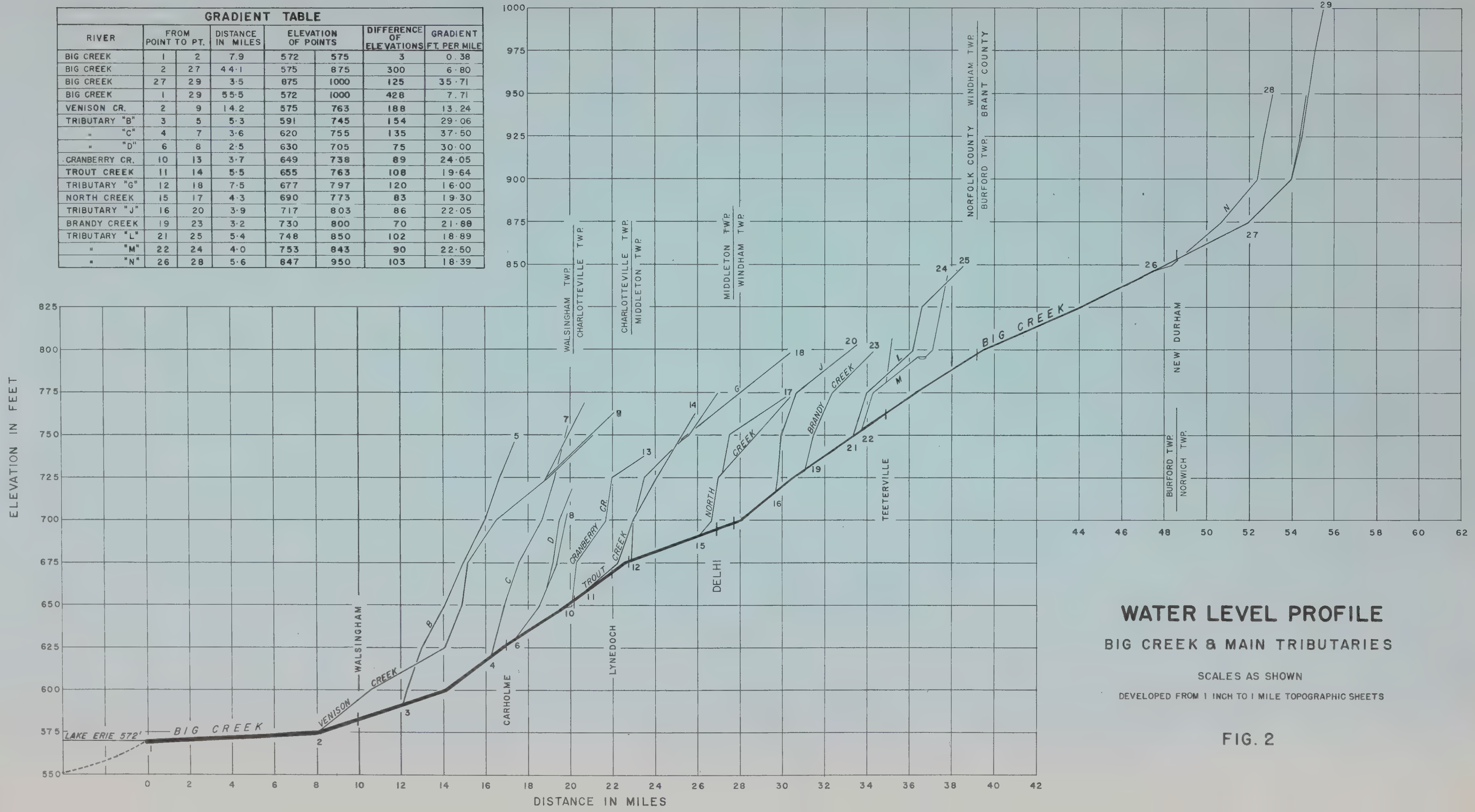
Young Creek rises 2½ miles north-west of the hamlet of Walsh and flows 10.8 miles to its mouth at a point

on Lake Erie about three miles south-west of Port Dover. It has a total fall of 203 feet and an average gradient of 18.8 feet to the mile.

(e) Nanticoke Creek

The Nanticoke Creek is the most easterly in the region, rising about half a mile south-east of the north-east corner of Windham Township; then flows south for about six miles before swinging eastwards at the town of Waterford. It continues in the easterly direction for about seven miles before heading southwards to Lake Erie. It passes through the villages of Rockford and Varenay and has its mouth one mile south of the village of Nanticoke and seven miles east of Port Dover. It is a long river; being 26.8 miles in length and with a total fall of 203 feet for an average gradient of 7.6 feet per mile.

GRADIENT TABLE							
RIVER	FROM POINT TO PT.		DISTANCE IN MILES	ELEVATION OF POINTS		DIFFERENCE OF ELEVATIONS	GRADIENT FT. PER MILE
BIG CREEK	1	2	7.9	572	575	3	0.38
BIG CREEK	2	27	44·1	575	875	300	6·80
BIG CREEK	27	29	3·5	875	1000	125	35·71
BIG CREEK	1	29	55·5	572	1000	428	7.71
VENISON CR.	2	9	14.2	575	763	188	13.24
TRIBUTARY "B"	3	5	5·3	591	745	154	29·06
" "C"	4	7	3·6	620	755	135	37·50
" "D"	6	8	2·5	630	705	75	30·00
CRANBERRY CR.	10	13	3·7	649	738	89	24·05
TROUT CREEK	11	14	5·5	655	763	108	19·64
TRIBUTARY "G"	12	18	7·5	677	797	120	16·00
NORTH CREEK	15	17	4·3	690	773	83	19·30
TRIBUTARY "J"	16	20	3·9	717	803	86	22·05
BRANDY CREEK	19	23	3·2	730	800	70	21·88
TRIBUTARY "L"	21	25	5·4	748	850	102	18·89
" "M"	22	24	4·0	753	843	90	22·50
" "N"	26	28	5·6	847	950	103	18·39



WATER LEVEL PROFILE

BIG CREEK & MAIN TRIBUTARIES

SCALES AS SHOWN

DEVELOPED FROM 1 INCH TO 1 MILE TOPOGRAPHIC SHEETS

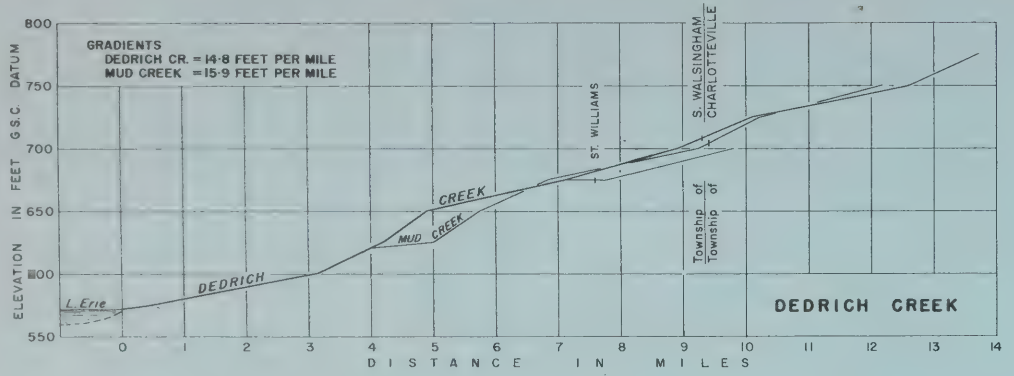
FIG. 2

WATER LEVEL PROFILES

NANTICOKE CREEK
DEDRICH CREEK
YOUNG CREEK
LYNN RIVER

SCALES AS SHOWN

DEVELOPED FROM ONE INCH TO ONE MILE TOPOGRAPHIC SHEETS



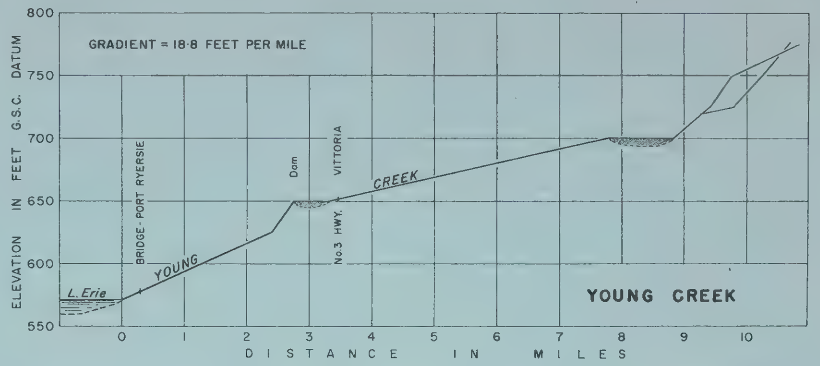
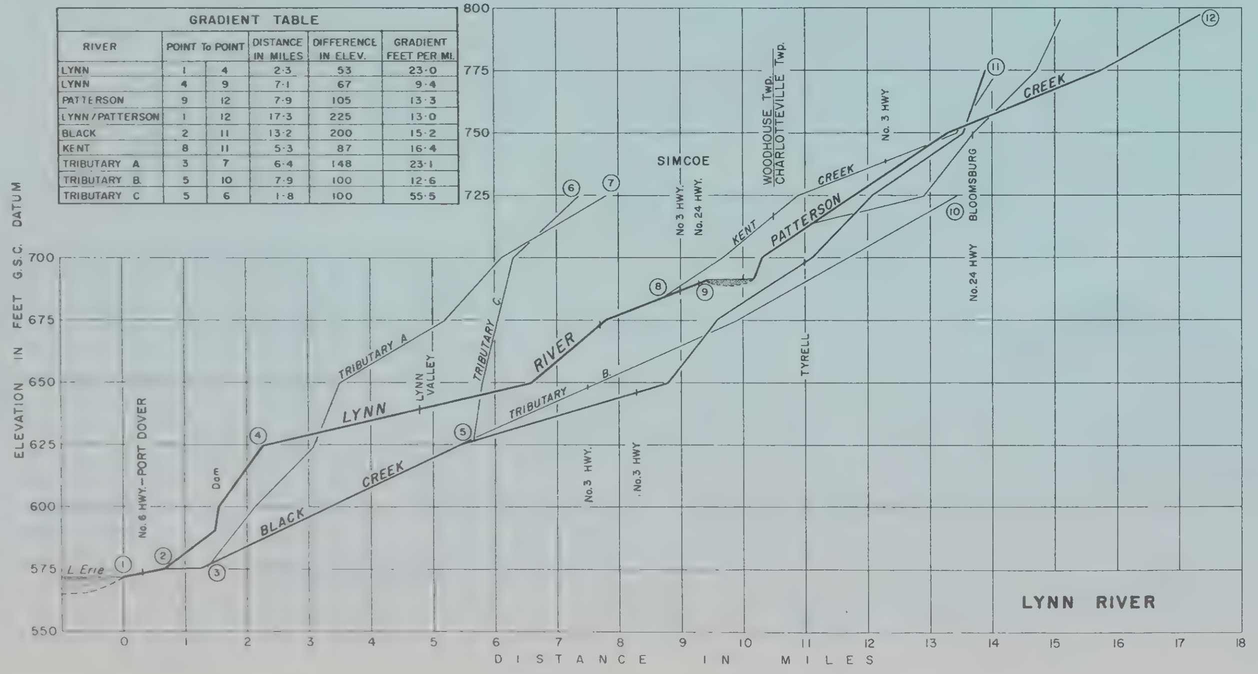
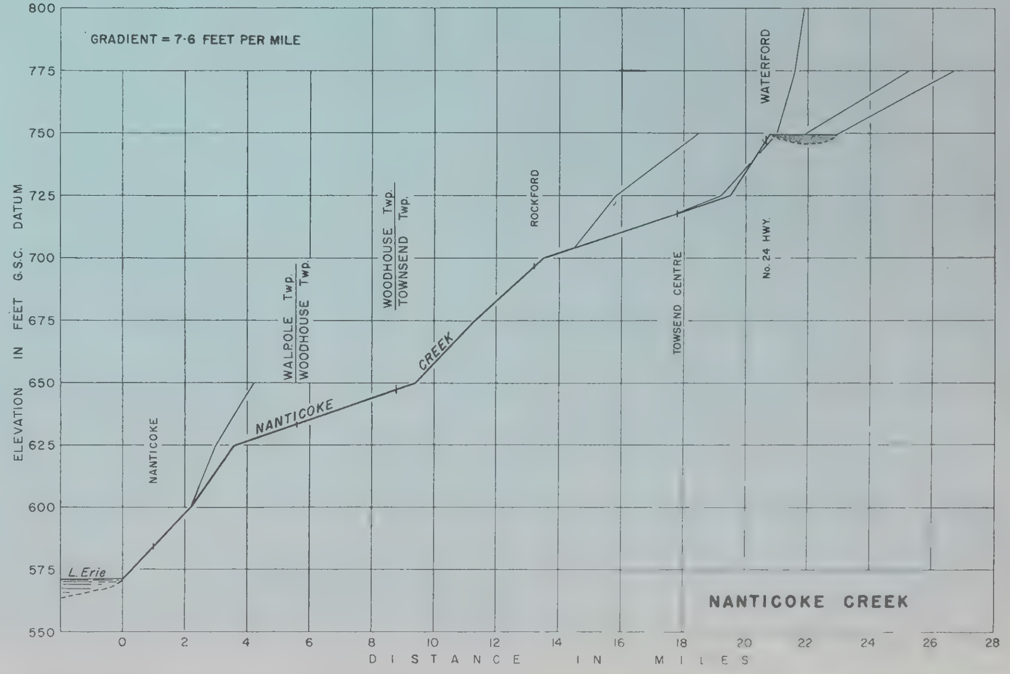


FIG. 3



GRADIENT TABLE					
RIVER	POINT To POINT		DISTANCE IN MILES	DIFFERENCE IN ELEV.	GRADIENT FEET PER MI.
LYNN	1	4	2·3	53	23·0
LYNN	4	9	7·1	67	9·4
PATTERSON	9	12	7·9	105	13·3
LYNN / PATTERSON	1	12	17·3	225	13·0
BLACK	2	11	13·2	200	15·2
KENT	8	11	5·3	87	16·4
TRIBUTARY A	3	7	6·4	148	23·1
TRIBUTARY B	5	10	7·9	100	12·6
TRIBUTARY C	5	6	1·8	100	55·5



CHAPTER 2

FORMER FLOODS

The earliest known references to floods on the Big Creek are to be found in the diaries kept by the surveyors who laid out the adjacent townships of Walsingham and Windham. The surveyors were required to record events and circumstances that affected the progress of their work, and they noted floods because the floods occasioned loss of valuable time, and because they wished to receive full pay for the time so accounted for. It is for this reason that the surveyors' diaries tend to emphasize the extent of the delay to which their work was subject, rather than the severity of the flood, or the height to which the waters rose.

Thus, on March 10, 1796, the surveyor William Hambly, running westward on the line of the front of the second concession of Walsingham, came to the Big Creek, "which was broken up and very high, went up Stream and crossed and continued Line."

In the spring of the following year, considerable flooding attended the breaking up of the streams; but the precise location of the occurrence is not stated, nor is it clear whether the streams overflowed their banks. In a letter to the Surveyor-General, dated May 25, 1797, Deputy-Surveyor Thomas Welch writes thus of his survey in Walsingham: "The frequent Rains that have fallen here this Spring immediately succeeding the very deep Snow, which has constantly kept the Swamps & low grounds so full of Water that we have been obliged to wade more or less every Day, & frequently a very considerable part of the Day, & very often knee Deep, and sometimes Waist Deep, which has broken up my party more than once by Sickness."

According to William Hambly's diary of his survey of Windham Township, there was a flood in November, 1797, on the Big Creek, while he was travelling eastward on the 8th Concession line of that township. His entries for the 4th, 5th, and 6th

of November read as follows:

> "4th, Saturday - rained all night, and continuing to rain, the waters began to rise
> 5th, Sunday - rain and snow all Day
> 6th, Monday, still snowing and waters up, left the work and went Home"

In 1798, Thomas Welch records a flood on Big Creek: "Tuesday 20th (March). On account of yesterday's rain, we found big Creek broken up, & so high that we could not cross it till we had travelled up on the Eastern side thereof ... so far as the 5th Concession line of Walsingham, where we got across & Encamped."

These records give the impression that flooding on Big Creek was an annual event (with a November flood thrown in for good measure); but the diaries cease with the completion of the surveys, and with their discontinuance, so far as the Big Creek watershed is concerned, the record comes to an end. Not until 1809 is there any further mention of Big Creek floods; in May of that year the Deputy-Surveyor Mahlon Burwell was travelling from Fort Erie to perform a survey in the Township of Southwold. May 29 found him at the house of Mr. Welch, in Charlotteville. His diary continues:

> "Tuesday 30th May. Set out early, Mr. Welch sent his Son to Pilot us to Big Creek, there being no Road to that place. Found the Creek very high in consequence of the great fall of Rain. Travelled to within four Miles of Big Otter Creek & encamped. Rained smartly in the night."

It is apparent that the state of the creek did not prevent him and his party from crossing. The next day he recorded that he felled a large Hemlock Tree by which to cross the Otter Creek; and on June 1, at Kettle Creek, "had to fall Timber across it .... and it Rained in the night".

Following Burwell's laconic reference to the May floods in 1809, there is an interval of twenty-seven years before the next known mention of floods in this watershed. In 1835, the Rev. Thomas Green was appointed as Travelling Missionary in the London District (which then included Norfolk County); the 22nd and 23rd of February, 1836, found him

travelling from Vienna toward Burford. The following passage is taken from his journal:

> "Monday 22nd .... a tedious drive (Vienna to Middleton), rendered more disagreeable by a sudden thaw.
> "Tuesday 23rd. I set out as soon as I had breakfasted for Burford, a drive of twenty-five miles - the roads in many places covered with water, in consequence of the continued thaw."

As Green gives no account of his crossing of Big Creek, it is impossible to determine from his journal whether the floods were caused by surface water (rain and melted snow), or whether the streams were overflowing their banks.

In June, 1836, Mr. Green encountered floods in the course of his journey from Middleton to Simcoe.

> "Saturday 25th (June). I proceeded to Simcoe, the day was boisterous and unpleasant, and the roads very heavy in consequence of the heavy rains which had fallen, I found the causeways dangerous, being deeply covered with water, and was obliged to let the horse pick his own way."

The next flood, of which mention has been found, on the Big Creek, occurred in the spring of 1843; the report of its occurrence contains the first reference to flood damage to property on this stream. The District Surveyor of the District of Talbot, which in 1841 had been separated from the District of London, was Mr. Thomas Allchin. In a report to the District Council, dated May 11, 1843, Mr. Allchin states that the bridge over Big Creek on Talbot Street (at the present village of Delhi) was "intirely washed away by the late freshets at the breaking up of the Winter." No further particulars are known.

Whatever floods, or even flood damage, there may have been in the course of the ensuing thirty-five years is not known; not even passing mention of it has been found.

One of the severest storms ever to visit this Province struck on September 13, 1878, and caused immense damage over a wide area. The damage done on Big Creek must have been very great; but the account that the Toronto Globe published reported only the damage at Teeterville and at McKnight's mill, a mile or so below that village. It is probable that reports

of damage elsewhere on Big Creek were crowded out of the news columns by the weight of more spectacular news from other parts of the Province. The following is taken from the Toronto Globe of Monday, September 16, 1878:

> "Teeterville, Sept. 14 - The bridge and dam at this place on Big Creek were last night forced out by the high freshet, causing considerable damage to property by flooding the mills, liberating the logs, and driving before it with fearful rapidity lumber piles, sheds, car track, and every moveable thing in its way, scattering them in confusion into the current of the stream. Every mill below must have been endangered by this unexpected break away, and serious loss must be the result through the length of the river. Communication is entirely cut off from the grist and sawmill but action will at once be taken to have everything reconstructed in a few days. It is difficult to give any estimate of the actual loss.
>
> "LATER.- A serious loss has resulted to the mill and dam of Mr. James McKnight from the breakaway at this place last night. Mr. McKnight hastened hither on learning that there was danger to Teeter's mills, but all efforts proved unavailing, and his dam withstood the fearful rush only a few hours. General havoc was the consequence. In lumber, timber, and logs the loss to Mr. McKnight must be indeed considerable, as his pond was filled with manufactured stock of all kinds. This has been followed by a total wreck of dams below, which will make the estimated loss on the river very great."

The next flood on Big Creek of which any account has been preserved took place fourteen years later, June 3, 1892, The Toronto Globe, of June 6, carried a brief report, which, nevertheless, sufficiently indicated the severity of the flood.

> "Delhi, June 4.- The freshet of last night and to-day is almost unprecedented in this locality. Nearly all the bridges have been swept away. The mills here narrowly escaped."

A few days later, on June 8, the Brantford Courier published a fuller account:

> "Windham Centre.- The heavy rain on Friday last (June 3rd) did considerable damage on Big Creek. There is not a bridge left on it across the whole township that a team can cross. The loss to the township in this particular will exceed $2,000, besides heavy losses to private individuals. The creek flats at Teeterville were flooded to the depth of four feet, the mill dam was taken away, and several lumber piles belonging to Mr. W.H. Teeter. There were three head of cattle seen going down the channel, two of them were dead and one still living, also one horse; they came some where from the north. Mr. Jas. McKnight also lost his mill dam. and several piles of lumber were carried to the woods. Mr. Quance, of Delhi, lost his mill dam, and his flouring mill and grain house came near going when the flood of water struck it. The houses on the low land at Lynedoch were flooded and the people were driven to the up lands for safety. No lives have been lost that we know of."

In the ensuing sixty-five years, from 1892 to 1957, there is evidence that floods have occurred on the Big Creek, and that they have done damage. The remains of a mill at Teeterville, and of more than one between Teeterville and Lynedoch, indicate some of the damage done. Considerable investigation, and persistent inquiry, have failed to attach a reliable date to any of these ruins; and the files of the Delhi News-Record, said to have been taken from the place of publication at the time of a change of ownership, have not been found. This state of affairs, unfortunately, cannot be taken to indicate that there have been no floods, but only that the records have, if made, remained undiscovered.

As a result of the haphazard methods by which the incidence of flooding has been recorded, it happens that, of 11 occasions when flooding was noted on the Lynn River, not one falls on the same date as that of a known flood on the Big Creek.

Thomas Welch, the Deputy-Surveyor, who, in 1798, noted a flood on the Big Creek in March, had been, in January of the same year, on the Lynn. On Tuesday, January 16, 1798, he made the following entry in his diary:

> "Yesterday being very wet & the Rain increasing & continuing all last night, has raised the Creeks, branches, low grounds & swamps, so verry full of Water, Ice &c., and withal the weather so excessively Cold, that it was impossible to do business to Day."

As Mr. Welch had arrived, on the 15th, "at Peter Walkers at the Mouth of Pattersons Creek, where we lodged" (the modern Lynn River), it is apparent that his observation applies to that stream, as well as to others in the vicinity. His entry for January 17 indicates that the high water continued through that day also. On the 18th, he proceeded to his survey in the Township of Woodhouse.

The next known observation of high water on the Lynn is recorded in the journal of the Rev. Thomas Green, on the 29th of March, 1836.

"I then set out (from Rainham) for Woodhouse, a distance of about thirty miles, and found much difficulty in passing, with the cutter, some of the streams, which were swollen by the thaw, and the ice so weakened as not to support the horse .... the ice broke in one place."

Mr. Green's next reference to high water may also be taken as a "flood" on part of the country drained by the Lynn River, though the precise location is not easy to determine. On April 9, 1836, he wrote:

"I set out (from Woodhouse) for Windham this morning. After travelling very slowly, the horse nearly up to the knees every step, the bridges and causeways all covered with water, in consequence of the heavy rain."

And on May 9, 1836, Mr. Green recorded still another occasion when the water was high on an unidentified creek in the same neighbourhood, as well as a reference to an earlier flood.

"I again left Mr. Mercer's (Lot 3, Concession II, Walpole Township) for the township of Woodhouse, and in my way was obliged to swim my horse across a deep creek, the bridges having been carried away by the freshets occasioned by the melting of the snow and rain in the beginning of spring."

On May 29, 1836, Mr. Green recorded the fourth time in the same year when the waters were high on or near Patterson's Creek.

"Sunday 29th. Being anxious to keep my appointment, I braved the storm, rising very early, but having ridden as far as Port Dover (on his way to The Lake Shore, east of that point), I found it was impossible to get forward, owing to the great rise of water in the Creek from the rain of the preceding days. Monday 30th, returned to Woodhouse."

The year 1836 was also marked by a flood on the Lynn River in October; and once again we are indebted to the Rev. Thomas Green for the record.

"Monday 17th (October, 1836). I left (Walpole) for Woodhouse; the travelling to-day was beyond anything I had yet experienced ... the roads covered with water and the trees almost stripped of their foliage ... I was obliged to stop at a tavern not being able to cross the bridge which connects Dover and Walpole, the waters of the creek having been so much increased as to cover to a great depth not only the bridge, but the surrounding flats."

After the lapse of thirty-seven years, the next known flood on the Lynn River was recorded by the Toronto Globe, April 10, 1873; the flooding occurred on the 8th and 9th.

> "Port Dover, April 9.- It has been raining here for three days. The creeks are very much flooded and several bridges are down. Travel is almost stopped."

No further particulars are known.

The next report of a flood on the Lynn was published by the Globe, February 9, 1900.

> "Simcoe, Feb. 8.- The mild weather of yesterday and the rain of today made havoc here with the bridges and dams. Reports come to hand to-night that Brooke's dam at Lynn Valley, together with parts of other dams, has been carried away by the freshet. The G.T.R. bridge, about a quarter of a mile from Simcoe town, situated on the line to Port Dover, was washed away this afternoon. It is feared other damage may be done unless the water in the Lynn goes down."

An unusually heavy rain fell at Simcoe, January 18, 1929, and flooded the entire north-western portion of the town. "The Lynn River on the outskirts of town overflowed its banks, and the freshets swept on into the low-lying districts, rendering highways impassable and invading hundreds of cellars." A big dam at Marr's Hollow (the present Marburg, Lot 18, Concession III, Woodhouse Township) was washed out; and considerable damage was done to the property of the Lake Erie & Northern Railway between Colborne and Simcoe. Two dams on the Lynn River were said to be threatened, "but their owners are hopeful that they will withstand the pressure."

Widespread flooding occurred throughout south-western Ontario in April 1937 and there is no doubt that serious flooding also occurred in the streams of the Big Creek Region. However, the following excerpt from a letter received from Mr. R.P. Quance is the only known reference to flooding in this area.

> "In the year 1937 and the month of April the power dam at Croton near Lynedoch went out, and the Quance Dam at Delhi was badly shaken. The water was only about two feet lower below the dam than above it, with the lower abutments and retaining walls under six to eight feet of water."

Throughout Western Ontario, severe flooding occurred on many streams in April, 1947. On April 5, 1947, the Lynn River at Sutton's Pond dam, in the town of Simcoe, was ten feet above normal. On that date, an employee of the

Riddell & McIntosh mill, in attempting to raise the waste-gate at the dam, fell into the water, and he and a would-be rescuer narrowly escaped drowning; but both men were brought safely ashore.

On February 17, 1954, the Simcoe Reformer reported that the Lynn River had been in a state of flood the previous day, the 16th:

> "Fed by unrelenting rain from the skies and a heavy runoff from the thawed ground, swollen streams and creeks spilled over their banks, ripped out culverts, and washed out several roads. ...... Climbing to a near record level, water burst the banks of the Lynn River and its tributaries in the district, lapping up to the doors of riverside homes and rushing into the ground floors of some residences.
>
> "The exact toll of damage in the county was not known. Several culverts were battered by cascading creeks and a number of township roads were under water."

Two reports of flooding have been definitely identified as having occurred on the Nanticoke Creek, one in March, 1852, the other in April, 1947.

That of March 18, 1852, is contained in a despatch published in a Toronto newspaper, in both its weekly and its semi-weekly editions, the North American, and consists only of the following statement:

> "It is said that Cayuga, Indiana, Nanticoke and Stoney Creek bridges have been carried away."

The widespread flooding that occurred on April 5, 1947, also affected the Nanticoke Creek. The severity of the flood on the Nanticoke, or the extent of damage done, is not known.

A flood on Big Creek above the Dam at Delhi — April, 1957.

Swollen Lynn River overflowing Sutton's Dam at Simcoe — February, 1954.

The Lynn River flooding Pond Street in Simcoe — February, 1956.

CHAPTER 3

HYDROLOGY

HYDROLOGY encompasses the behaviour of water as it occurs in the atmosphere, on the surface of the ground, and underground. The movement of water from the atmosphere to the ground and back again to the atmosphere is called the "hydrologic cycle". There are many factors which influence the water movement, and particularly that portion between the incidence of precipitation over land areas and the subsequent discharge through stream channels or direct return to the atmosphere by evaporation and transpiration.

The drainage area of the Big Creek region is subject to the constant phases of the hydrologic cycle and like other areas, problems exist which are peculiar to the prevailing climatic conditions and the physical characteristics of the area.

1. Precipitation, Stream Flow and Run-Off

(a) Precipitation

The word "precipitation" as used in Meteorology includes all moisture that reaches the earth, whatever its form - rain, snow, sleet, or hail. The most significant of these are rain and snow. Throughout the Lake Erie-Niagara Peninsula region, the average annual precipitation is 33.7 inches, determined from local meteorological stations with records of observation ranging from 21 to 45 years.

The Big Creek area is in approximately the centre of this region and from stations within and adjacent to it, with periods of observations ranging from 18 to 20 years, the annual average precipitation is 34.3 inches.

Precipitation, of course, is most significant since it is the source of all stream flow. In many areas there are sufficient reliable data available for generalized estimates of this factor, but on the whole, additional self-recording precipitation stations are required for a more accurate evaluation of the precipitation - run-off relationship.

(b) Stream Flow

Stream flow, or run-off, consists of surface flow and ground water which is constantly entering the stream channel along its course and is broadly the excess of precipitation over evapotranspiration and deep seepage. Surface flow is that portion of rainfall, melted snow and/or ice which reaches the stream channels directly by flowing over the ground surface.

Ground water flow (percolation) is going on continuously and is responsible for maintaining the flow in streams, during periods of drought. This portion is usually classified as base flow.

Measurements of stream flow have been recorded at Port Rowan near the mouth of Big Creek for a period of 29 months only, during the years 1945 to 1948. This observation point was abandoned during 1948, owing to the unstable nature of the cross-sectional area at the measuring point, but four (4) new hydrometric stations were established in the Big Creek area during the past three years, namely:

(1) North Creek near Delhi, October 1954

(2) Big Creek " " " 1955

(3) Big Creek near Walsingham, November 1955

(4) Lynn River near Simcoe, December 1957. (No records).

Table 3 shows the maximum and minimum mean daily and mean monthly flows for the period of records and Fig. 4 shows the hydrographs for the same period.

The factors affecting run-off are numerous and varied and appear in so many combinations, that it is difficult to classify them in any order relative to their direct effect on run-off. If quantitative results only are required, the best means available is to measure the run-off directly by the use of hydrometric gauges at strategic locations. Here again the use of self-recording instruments is desirable.

BIG CREEK

MAXIMUM AND MINIMUM MEAN DAILY AND MEAN MONTHLY FLOWS IN CUBIC FEET PER SECOND

TABLE 3

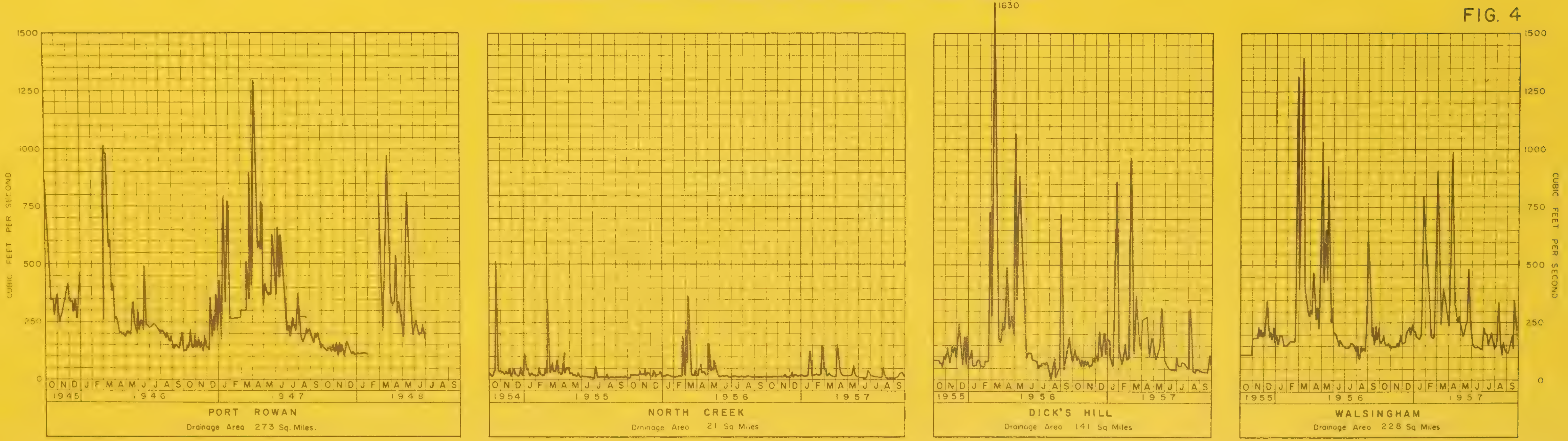
GAUGE	YEAR	OCTOBER			NOVEMBER			DECEMBER			JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE			JULY			AUGUST			SEPTEMBER		
		MAX	MIN.	MEAN	MAX	MIN	MEAN.	MAX	MIN.	MEAN.	MAX	MIN.	MEAN.	MAX	MIN.	MEAN.	MAX.	MIN.	MEAN.	MAX.	MIN.	MEAN.	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX.	MIN	MEAN
PORT ROWAN	1945-46	990	281	466	461	253	309	453	240	321	—	—	—	—	—	—	1010	281	600	274	181	223	331	171	223	493	198	248	260	198	222	267	152	191	171	125	150
	1946-47	222	118	139	198	118	148	368	125	214	795	166	434	—	—	269	905	—	409	1270	324	690	665	273	429	845	232	460	273	188	235	225	165	200	225	135	184
	1947-48	150	112	129	160	108	129	171	104	136	—	—	—	—	—	—	976	194	525	544	259	162	815	188	376	252	176	212	—	—	—	—	—	—	—	—	—
NORTH CREEK	1954-55	511	9	54	35	18	24	43	16	22	195	14	28	91	12	28	289	21	59	121	16	36	35	12	17	15	8	10	62	6	10	20	8	9	15	8	8
	1955-56	32	7	17	38	18	25	47	14	25	18	10	13	181	10	25	360	18	63	162	18	36	93	18	46	18	10	16	18	14	14	23	14	17	18	10	15
	1956-57	14	10	12	23	10	13	32	14	21	127	12	26	144	14	25	47	18	26	153	18	36	70	14	21	47	8	14	18	10	14	83	7	15	38	10	14
DICK'S HILL	1955-56	102	51	76	138	70	112	242	55	119	170	52	80	737	50	128	1630	165	495	1100	146	287	890	100	400	123	67	92	79	49	66	711	6	80	720	45	190
	1956-57	130	62	91	119	59	79	201	85	146	861	56	201	972	66	179	545	112	239	1060	100	282	308	85	139	137	40	61	137	53	80	311	32	62	141	37	72
WALSINGHAM	1955-56	115	115	115	228	180	192	285	162	216	204	149	166	1310	153	264	1400	263	562	682	227	333	1030	216	483	212	145	169	174	121	146	698	91	177	665	169	263
	1956-57	203	149	166	199	141	160	281	171	221	798	170	291	900	189	271	668	232	314	785	228	359	487	177	242	231	129	160	218	129	175	334	106	141	353	114	174

HYDROGRAPHS

MEAN DAILY FLOWS BIG CREEK

Mean daily flows plotted from records of the Water Resources Branch, Dept. of Northern Affairs and National Resources, Ottawa

FIG. 4



Stream flow, or run-off, is the resultant of all the watershed characteristics, and while it indicates the combined effect of the various features of the precipitation that falls on an area, it does not indicate the effect of any one factor.

Measuring and timing surface flow, or direct run-off, are most important, since reliable data concerning them make possible a more accurate solution of the particular problems of flood control and water supply.

2. Maximum Flows

(a) Spring Freshets

Where structures such as dams are concerned, it is not the ordinary or average flows that are significant, but the unusual or exceptional ones that may have occurred in the past, or may reasonably be expected to occur in the future. These flows provide the basic design criteria for all major water impounding structures whose failure could result in the loss of life and destruction of property. Therefore it is necessary, in the analysis of the data available, to forecast probable maximum conditions in direct relation to the human and economic factors involved.

From the records available for the Big Creek area it appears that maximum flows have occurred during the spring freshet months of March and April. The maximum recorded was 1,630 c.f.s.* and occurred in March 1956.

This is equivalent to 11 c.s.m.† As this is a mean daily flow it is very likely that the actual peak was in excess of this and may have been approximately 2,360 c.f.s. or 17 c.s.m. This peak was determined by Fuller's formula relating mean daily to peak flow.

This is a very low rate of run-off for a spring freshet flow and indicates the high retention capacity of the watershed.

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* Cubic feet per second.
† Cubic feet per second per square mile.

The geographic location of the watershed also has a direct bearing on that portion of spring run-off due to snowmelt. The total annual average snowfall estimated from records of stations operating in this area is approximately 54 inches, and with intermittent periods of warm weather throughout the winter months there is no significant amount of snow accumulation.

Further examination of the precipitation records show that only on rare occasions is there evidence of snow of depths with a water equivalent of one-half inch, or more, being on the ground at the time of, or immediately prior to, the spring break up.

Apparently the greater proportion of the annual snowfall melts and percolates through the sandy soils to recharge the ground water storage, and appears as stream flow later on in the season.

The estimated peak flows as determined from the recorded mean daily flows to date, at the various locations where hydrometric gauges have been established, are shown in the following table.

MAXIMUM MEAN DAILY AND ESTIMATED PEAK FLOWS
FOR GAUGE LOCATIONS ON BIG CREEK

Stream Gauge	Period of Record	Drainage Area Sq.Mi.	Maximum Flow			Date
			Mean Daily c.f.s.	Est'd Peak c.f.s.	Rate c.s.m.	
*Pt.Rowan	29 months	273	1,270	1,800	7	Apr.1947
North Cr.	19 "	21	511	922	44	Oct.1954
Delhi	6 "	142	1,630	2,360	17	Mar.1956
Walsing-ham	5 "	228	1,400	1,950	9	Mar.1956

* Discontinued 1948.

The foregoing table shows the maximum recorded flow as having occurred at the spring break up of 1956. It is probable, however, that flows of greater magnitude have occurred prior to this date, but as there are no actual discharge data available prior to 1946, it is difficult to estimate what has happened in the past. Fig. 5 shows some of the greater flows of spring and other seasons, as recorded to date. There are references in newspapers and diaries and eye-witness accounts of flooding, and flood damage in other years before systematic records were kept, by people living near the rivers in this area, and it appears that the spring flow of 1937 was of greater magnitude than any reported since that time.

From these reports it appears also that a great deal of flooding has occurred during other seasons than spring, i.e. from May through to October and November. There are quite a number of reports of flash floods occurring during the summer and autumn months.

(b) Other than Spring Freshets

In recent years it has become apparent that flood run-off, resulting from rainstorms without the aid of melting snow and ice is more significant, and in many instances of a magnitude in excess of that experienced in the spring freshet period.

The most obvious example of this is the hurricane storm of October, 1954, which caused such widespread damage and loss of life in Southern Ontario. Since that time a new concept of the rainfall-run-off producing type of storm has been gained, particularly in relation to the seasonal operation of flood control structures such as dams.

This is not to say that the usual spring floods will not continue to cause damage and even loss of life on a recurring basis, as indeed they will if not controlled, but with the contribution of hydrometeorology, the analysis and application of the run-off producing potential of the varying storm types, a more rational approach to the solution of these

problems may be achieved. Fig. 5 shows the hydrographs of some spring and other seasonal flows, as observed to date.

3. Unit Hydrographs

Where reasonably accurate rainfall and stream flow records are available, the use of the unit hydrograph method provides a solution to the problem of design storm flow.

Stream flow records for the Big Creek Region are of short duration, and observations are made once or twice a day, except on occasions when readings are taken at lesser time intervals of one or two hours during periods of high water.

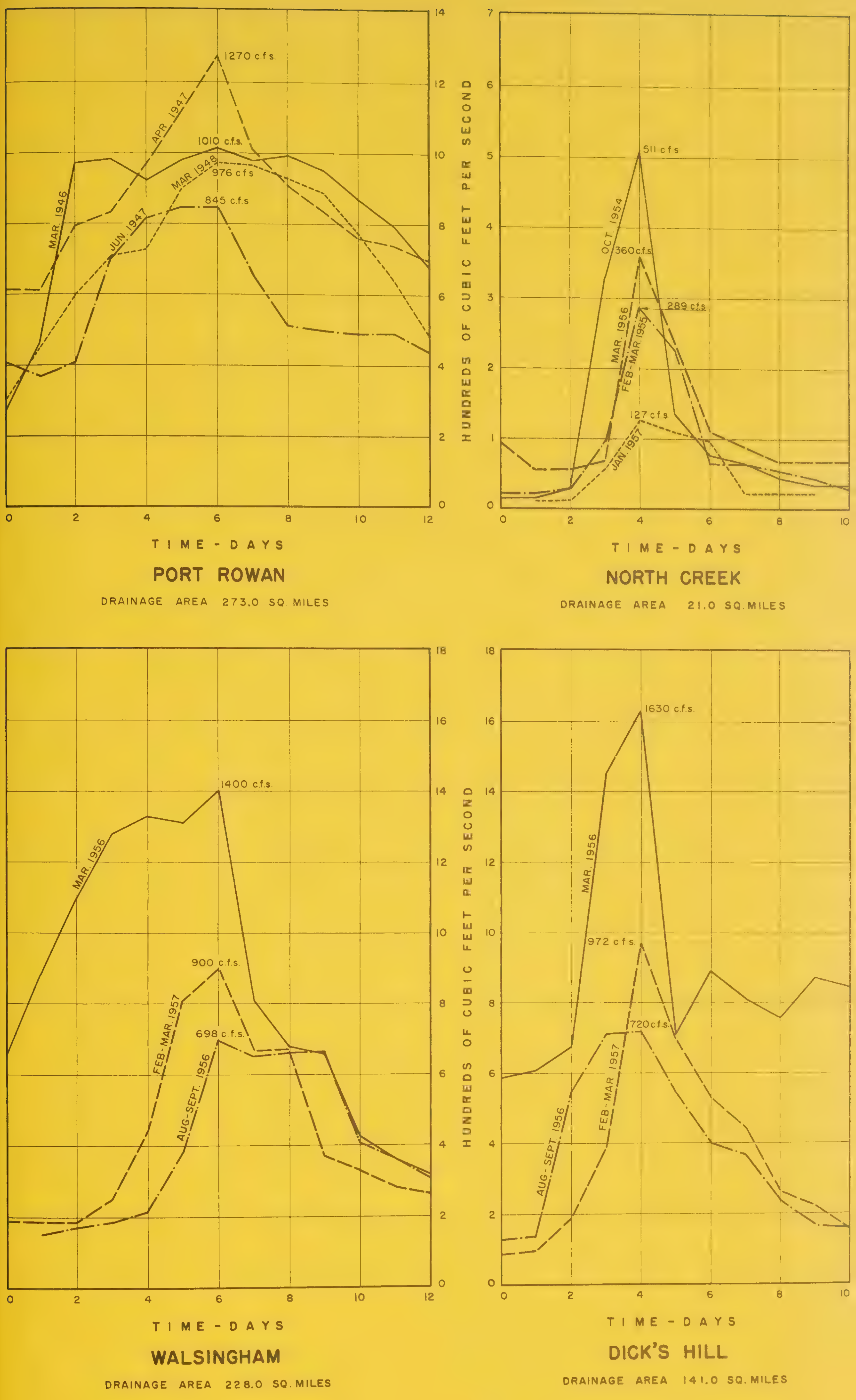
The gauges in operation at the present time are of such recent establishment that sufficiently accurate rating curves have not been developed to provide reliable flow data for the purpose of determining design storm flows by the unit hydrograph method alone.

There is one rainfall observation station in the Big Creek watershed at Delhi, and others at Waterford, St. Williams and Simcoe within the boundaries of the Big Creek Region. To determine the actual rainfall duration period of storms it was necessary to depend on records of the self-recording gauges at London and St. Thomas.

From the available mean daily flow, and rainfall records, unitgraph ordinates were determined for all the available run-off periods where conditions were suitable for this method.

As there were no timed flows available the problem of determination of peak ordinates must of necessity be resolved through the use of empirical formulae or other means. The Big Creek Region is similar to the Otter Creek area in regard to area, shape, soils, etc., but differs widely when such items as slopes, types of cover, drainage, retention areas, etc., and the various combinations of these items are considered.

The use of Fuller's formula relating mean daily to momentary peak was also considered, but it was found to



HYDROGRAPHS

SPRING AND OTHER SEASONAL FLOWS

MEANS DAILY FLOW PLOTTED FROM RECORDS OF THE WATER RESOURCES BRANCH, DEPT. NORTHERN AFFAIRS AND NATIONAL RESOURCES, OTTAWA.

FIG. 5

produce ratios out of proportion to the type of drainage area with which we are concerned. Finally a combination of the Fuller's formula and the comparison method was used, relying heavily on simple areal proportion, and the resulting ratio of peak to mean flow was 1.43, i.e. the momentary peak flow would be approximately 43 per cent greater than the recorded maximum mean daily flow for the area of the North Creek.

Another method suggested by Langbien* is where the ratio of peak flow to maximum daily flow, determined from the ratios of mean flow on the maximum day to the average flow on the days immediately preceding and following the maximum day, was used. The resulting ratio for peak flow to mean daily flow from the records available for the North Creek area was 1.35. This is an average ratio based on six different flow periods including summer, autumn and spring periods.

The generalized chart from which this ratio was procured is based on data from drainage areas in the United States, but the units used and the basic reasoning involved should make this applicable in many places outside of the areas from which the data were procurred. There is no doubt that more reliable results could be obtained by developing similar charts from data from the areas under consideration, but in this instance there are practically no data available, and it is felt that the ratio of 1.35 as derived from the Langbien method is sufficiently reliable for the purpose at the present time.

Table 4 shows the results of the unitgraph determinations, with the peak ordinates as found by Langbien method.

The peak ordinates found for North Creek were plotted against rainfall duration to ascertain if a possible correlation existed, from which intermediate unit peak

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* Langbien W.B., Peak discharge from Daily Records, U.S. Geol. Survey Water Resources Bull., Aug. 10, 1944.

TABLE 4

UNITGRAPH DISCHARGES FOR BIG CREEK AND NORTH CREEK AT DELHI FOR SELECTED PERIODS

<u>Drainage Areas</u>: Big Creek at Delhi = 142.0 sq. miles
North " " " = 21.0 " "

Gauge Location	Date	Unit Discharge - c.f.s.		Rainfall		Run-off	
		Max. Mean daily	Peak*	Inches	Hours	Inches	Per Cent
North Creek at Delhi.	July 1955	409	443	0.41	2	0.14	34
	April 1956	312	364	2.44	30	0.39	16
	Oct. 1954	294	338	4.88	48	1.59	33
	March 1956	336	384	1.85	60±	0.82	44
Big Creek at Delhi	Aug. 1956	922	994	2.66	3-4	0.58	22

* Langbien method

ordinates may be interpolated. The plotted points fitted very well to a straight line, and the resulting interpolated unit peaks and rates of discharge are shown in the following table.

Duration of Rainfall in Hours	Unit Peak Discharges c.f.s.	Peak Rate Of Discharge c.s.m.*
2	452	21.5
6	443	21
12	427	20
18	412	19.6
24	392	18.7
36	365	17.4
48	338	16
60	305	14.5

The above table is for the North Creek area only. Unfortunately records for the other gauges in the Big Creek area are of such short duration that it was impossible to attempt the application of the unitgraph method, except in one instance as noted in Table 4, where the peak unit at Delhi was determined as 994 c.f.s., or 7 c.s.m. for a drainage area of 142.0 square miles.

It should be noted here that all unitgraph discharges have been compiled from sparse data, and should be used only as a guide, until further revision is effected by procurement of more refined data.

4. Design Storms

The "design flood" flow is generally referred to as the hydrograph or peak discharge that is finally adopted as the basis for the design of any particular structure. This flow is dependent on a consideration of the flood

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* Cubic feet per second per square mile.

characteristics of the particular area, and on economic and other pertinent practical considerations.

Usually it is practical to accept a limited degree of risk in the selection of a design flood flow, except for cases where the maximum degree of protection is desirable because of the possible loss of life or excessive damage to valuable property should the structure fail.

The flood damage in the Big Creek Region has not been serious and the extent and occurrences have been outlined in chapters 2 and 4. Actual records show that excessive stream flow usually occurs during the late winter and early spring seasons. However, it is known that a storm such as occurred over Southern Ontario in October 1954, if concentrated over the Big Creek area, could produce run-off considerably in excess of anything previously experienced.

(a) Hurricane Hazel

The hurricane-type storm known as "Hazel" extended over the Big Creek Region, and precipitated excessive amounts of rain during October 14, 15 and 16, 1954.

The amount of rain, and its estimated distribution are shown in Tables 5(a) and 5(b).

From Tables 5(a) and 5(b) it can be seen that fairly large amounts of rain, covering all of the region, were experienced. As in most other areas in Southern Ontario, ground conditions were in varying degrees of saturation owing to intermittent rain occurring during the two weeks prior to the storm.

Normally, with such rainfall amounts, and with surface conditions as existed in most areas, some flooding would be expected.

However, no reports are available in this office of any flooding of a serious nature occurring in this region as a result of this storm. This may be attributed to various conditions, most significant of which would be the surface and sub-surface soil formations of this area, which are dominantly of a sandy nature and conducive to rapid infiltration and deep percolation.

TABLE 5(a)

TOTAL RAINFALL IN THE BIG CREEK AREA DURING HURRICANE HAZEL

Station	Rainfall - Inches				
	Oct. 14	Oct. 15	Oct. 16	Total 48 hrs.	Total 60 hrs.
Aylmer	2.44	2.97	1.15	5.41	6.55
Clear Cr.	0.88	2.83	0.27	3.71	3.98
Delhi	1.62	3.15	0.90	4.77	5.67
St. Thomas	1.38	1.97	0.77	3.35	4.12
St. Williams	1.08	2.92	0.26	4.00	4.26
Simcoe	0.95	2.97	0.32	3.92	4.24
Waterford	0.91	2.97	0.25	3.88	4.13
Brantford	1.26	2.68	0.53	3.94	4.47
Woodstock	1.36	1.74	0.37	3.10	3.47
Caledonia	0.93	4.10	0.38	5.03	5.41
Hagersville	0.93	2.87	0.33	3.80	4.13
Kohler	1.32	3.47	0.17	4.79	4.96
Jarvis	0.03	4.17	0.41	4.20	4.61
Port Dover	-	3.73	0.09	3.73	3.82
London	1.83	2.24	0.40	4.07	4.47

TABLE 5(b)

* DISTRIBUTION OF TOTAL RAINFALL OVER BIG CREEK REGION DURING HURRICANE HAZEL.

River Area	Rainfall - Depth in inches on the Area	
	48 hours	60 hours
Big Creek - Total	4.23	4.78
Big Cr. (above Delhi)	4.27	4.89
Big Cr. (below Delhi)	4.44	5.02
Clear Creek	3.90	4.00
Dedrich Creek	4.01	4.32
Young Creek	4.17	4.25
Lynn River	4.05	4.36
Nanticoke Creek	4.02	4.44
North Creek	4.88	5.70

* Distribution estimated from isohyetal map.

The following table will give some idea of the net run-off experienced from a few of the storms which have been recorded for the area.

TABLE 6

RAINFALL AND RUN-OFF FOR SELECTED PERIODS FOR GAUGES IN THE BIG CREEK WATERSHED

Stream Gauge	Date	Rainfall		Run-off	
		Depth Inches on Area	Duration Hours	Depth Inches on Area	Per Cent
Big Creek at Port Rowan	Oct.1945 June 1947 May 1948	2.75 1.82 3.80	48 48 12 days	0.36 0.34 0.61	13 19 16
North Creek near Delhi	Oct.1954 July 1955 May 1956	5.70 0.42 2.44	60 2 30	1.82 0.15 0.38	32 35 16
Big Creek at Walsingham	Aug-Sept. 1956	2.24	4	0.32	14
Big Creek Near Delhi (Dick's Hill)	Aug-Sept. 1956	2.66	4	0.58	22

From the above table it is apparent that the run-off factor is not large, which is mainly due to the high absorbtive capacity of the surface and sub-surface soils.

Even in the case of the Hazel storm, when the rainfall was excessive over a wide area with periods of high intensity which would tend to increase the amount of run-off, the run-off factor was relatively low. Unfortunately only one stream gauge, located on North Creek near Delhi, was in operation at the time of this storm.

To estimate the effect of storm Hazel centred over the area, the total storm isohyetal map was superimposed over the Big Creek area and oriented so as to produce the maximum rainfall in terms of depth in inches on the area.

This isohyetal map for the storm centre was obtained by making use of all the available official records, plus additional reliable unofficial observations obtained from areas where no official observation stations are maintained. The average depth in inches on the areas as determined from the superimposed isohyetal map, are as follows:

Area	Depth on Area
Big Creek (Total Area)	8.20 inches
Big Creek Above Delhi Gauge	8.56 inches
North Creek Above the Gauge	9.53 inches

The actual rainfall period during the Hazel storm as it occurred over the area was approximately 60 hours.

One of the most significant factors in the application of the unitgraph technique is the determination of a reasonably accurate run-off coefficient. This depends on a variety of factors and combinations thereof, and is most uncertain, varying widely with the degree of perviousness of the watershed area, season of the year, the general climatic conditions, previous precipitation, rainfall intensity, etc.

There are not sufficient data available to arrive at a conclusive run-off factor, but from those which are available, the highest percentage run-off was approximately 44, which occurred during a spring run-off period and would be considered low for most areas.

The next highest percentage run-off occurred during the storm of October 1954 and was approximately 32 per cent.

From a study of the available storms the run-off percentages ranged from 13 to 44, from which it can be seen that the factor differs widely due to the variation in volume, intensity and distribution of the rainfall and the antecedent surface and sub-surface condition of the drainage area. With

the few records available it is difficult to get any correlation or conclusive results.

Since the desirable long-period records are not available and as we are mainly concerned at this point with estimating the peak flow of a design storm of large proportions, the problem becomes a matter of determining a specific run-off factor for this storm.

From recent studies and experience it is likely that the storm that would be most effective in terms of run-off would be the hurricane-type storms which occur in the late summer and autumn months rather than spring. As mentioned before, the maximum run-off for this type of storm, for the period of record, occurred in October 1954. This produced a 32 per cent run-off factor for an average rainfall of 5.7 inches over a period of 60 hours in the North Creek area.

The run-off from the neighbouring Otter Creek area for the same storm was 28 per cent from a 6.12-inch rainfall over a period of 60 hours,and it is estimated that the run-off for the whole of the Big Creek area was approximately 25 per cent. This takes into consideration the rainfall amounts and intensities over the larger area.

In view of the run-off factors determined from the actual Hazel storm as it occurred on this area it is estimated that the run-off, should a storm of this magnitude centre over the area, would approach 42 per cent on the total area, and 53 per cent for the area of North Creek. This increase in the run-off factor over the actual occurrence is approximately proportionate to the increase in total rainfall.

By applying the results of the unitgraph computations, it was estimated that a unit peak for a storm of this nature, would be 305 c.f.s. for the North Creek area with a resulting peak flow of 1,540 c.f.s., or 73 c.s.m.* at the gauge on North Creek.

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* c.s.m. = cubic feet per second per square mile.

(b) Probable Maximum Storms

From a depth-duration-area analysis of hurricane-type storms*, it was determined that a total rainfall of 18.1 inches in 48 hours could occur over the 21-square mile area of the North Creek watershed. Assuming a run-off factor of 63 per cent for this type and duration of storm, the run-off would be 11.4 inches.

Using the unit peak of 338 c.f.s. as interpolated from the table of unitgraph peaks, a run-off of this magnitude would produce a peak flow of 3,860 c.f.s. or 183 c.s.m. at the gauge on North Creek.

In addition to the hurricane-type storms, thunderstorms are often accompanied by intense rainfall and while their duration and extent are generally less than those of the hurricane-type storms, they often produce higher rates of run-off from areas of 500 square miles or less.

From the data available and further since most of our data are applicable only to the North Creek area of 21 square miles, it was determined that the storm which would likely produce the most critical run-off conditions for an area of this size would be the 6-hour thunderstorm which could precipitate about 15.8 inches of rain. This probable maximum thunderstorm was derived from 6-hour thunderstorms which have occurred in the United States and which are considered transposable to this area.

Because of the general nature of the soils, and the general physical characteristics of the area, the intensity of such a rainfall, and the known values of run-off, it is assumed that the run-off for the probable maximum 6-hour thunderstorm would approach 75 per cent.

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* Preliminary estimates of Probable Maximum Precipitation over Southern Ontario, by J.P. Bruce, Conservation Branch Department of Planning and Development.

With a 75 per cent run-off factor this storm would produce a run-off of 11.85 inches. Applying this to the interpolated 6-hour unit peak value of 443 c.f.s., results in a peak flow for the gauge on North Creek of 5,250 c.f.s., or 250 c.s.m.

This probable maximum peak flow of 250 c.s.m. has been used to estimate the spillway capacities of the various damsites in the watershed and is modified only in direct proportion, as the rainfall amounts would vary with the size of the areas above the damsites. These figures are shown in a table in another chapter of this report.

5. Low Flows

From the available streamflow records for all the gauges in the Big Creek Region shown in Table 3, it can be seen that periods of low flow usually occur in July, August and September, and occasionally in October, November and December.

TABLE 7

MINIMUM FLOWS RECORDED OVER THE PERIOD OF OBSERVATION

Big Creek at Port Rowan	December 1947	104 c.f.s.
Big Creek near Delhi	August 1956	6 c.f.s.
Big Creek at Walsingham	August 1956	91 c.f.s.
North Creek near Delhi	July 1955	6 c.f.s.

The average of the monthly mean flows is lowest for the period July to September, with August usually the lowest month for all areas.

Table 7 summarizes the low flows recorded at gauges on the Big Creek and its tributary North Creek for the period of records. These apply only to the gauge sites and

during these periods of drought many of the smaller tributaries would have little or no flow.

The flow of 6 c.f.s. recorded for the Big Creek area, near Delhi, is equivalent to 3,233,160 imperial gallons per day.

CHAPTER 4

WATER PROBLEMS

1. Introduction

Water is the nation's most valuable resource. It sustains life, grows crops, generates electric power, disposes of sewage, acts as transportation lanes, provides places for recreation to name just a few of the assets it provides. Without water, the earth degenerates to dry, arid deserts, devoid of any life and useless to mankind.

And yet, although these assets are obvious to any thinking person, this resource is too often the most neglected. It is allowed to be polluted; quite often the headwaters are destroyed resulting in dried up streams during the summer months; the natural water-holding capacity of the soil is upset by incorrect agricultural practices resulting in flash run-offs and destructive floods. Allowed to continue unchecked, this trend will turn many of the province's rivers and streams into liabilities rather than assets.

Fortunately, responsible people in the province have taken steps to protect this resource. Today there are nineteen established Conservation Authorities throughout Ontario and it is expected that more will be organized in the near future. One of the chief concerns of these groups is to ensure a more equitable balance between periods of excessive run-off and low flow. This means storing water and, in some cases, wisely controlling its distribution. At the present time, most of the water demands in the Big Creek Region are met by the ground water storage. Most farms draw water from wells, a practice which is also followed by larger communities; Simcoe, for instance, draws 660,000 gallons per day from springs or wells and Waterford draws 110,000 gallons per day from springs. Delhi, on the other hand, takes 200,000 gallons per day from North Creek while Port Dover and Port Rowan pump directly from Lake Erie. Both streams and wells are used for

livestock watering purposes whereas wildlife, of course, use only the natural source. Irrigation water is obtained primarily from dug-out ponds which are fed by the ground water. Concentrated pumping from streams does occur, quite often resulting in dry streams for a few days.

The demand for water in commercial and industrial establishments is not too great at the present time and is chiefly confined to the processing of agricultural products, such as fruits, vegetables and dairy products. However, with the industrial boom presently underway in Ontario and with the completion of the Seaway it is expected that the demand for water for these purposes will increase rapidly in the next few years.

Many of the municipalities and most of the commercial and industrial establishments depend upon the streams to carry away their waste products and, while this has not created too much of a hardship on the other water users as yet, it will certainly become worse unless suitable measures are taken to prevent it.

Mechanical and electric power can be obtained from the river by the use of water wheels or turbines. It is necessary that a reliable flow of water be maintained wherever these have been built. Although the Big Creek Region is not endowed with a high hydro-electric potential, small plants have been built in the past on the various streams throughout the watershed. Data concerning these plants can be found in Table 8 which is an extract from a pamphlet entitled "List of Water Powers in the Province of Ontario", published in 1946 by the Ontario Department of Lands and Forests.

Problems do exist to some extent now with the multiple uses of the water and, for any conservation scheme to be a success, much co-operation, tolerance and understanding should be exercised by all parties concerned.

TABLE 8 LIST OF WATER POWERS IN THE BIG CREEK REGION

River and Power Sites	Site Numbers		Head in feet	Drainage Area Sq. Mi.	Est. Capacity in H.P. at 80% Efficiency		Installed H.P.	Remarks
	Undev. Site No.	Power Dev. No.			At ordinary min. flow	At ordinary 6-mon. flow		
Big Creek (Lake Erie Drainage)-								
Teeterville	-	2GC27	9	81	7	18	70	
Delhi	-	2GC24	12	121	13	36	56	
$\frac{1}{3}$ mile west of Delhi	2GC1	-	16	121	17	48	-	Formerly developed
$3\frac{1}{2}$ miles south-west of Delhi	2GC2	-	22	143	28	78	-	Formerly developed
Cranbrook (Trib. to Big Cr.)-								
1 mile from Lynedoch	2GC3	-	18	8	1	4	-	Formerly developed
Spring Creek (Trib. to Big Cr.)-								
2 miles from Port Rowan	-	2GC8	12	25	3	7	30	
2 miles from Port Rowan	-	2GC10	16	25	4	10	40	
$1\frac{1}{2}$ miles from Port Rowan	-	2GC23	10	25	2	6	40	
Clear Creek (Lake Erie Drainage)-								
Clear Creek	-	2GC28	(12)	22	2	6	18	
Lynn (Lake Erie Drainage)-								
Simcoe	2GC6	-	10	60	6	15	-	Formerly developed
1 mile south of Simcoe	-	2GC22	14	66	8	23	135	
$2\frac{1}{2}$ miles south-east of Simcoe	-	2GC30	8	70	5	13	53	
5 miles east of Tillsonburg	2GC7	-	13	77	9	25	-	Formerly developed
Port Dover	-	2GC18	13	123	14	39	100	
Patterson's Creek (Trib.to Lynn)-								
Simcoe	2GC8	-	12	7	1	2	-	Formerly developed
Nanticoke (Lake Erie Drainage)-								
Waterford	2GC9	-	18	20	3	9	-	Formerly developed
$2\frac{1}{2}$ miles below Waterford	2GC10	-	7	28	2	5	-	Formerly developed
Nanticoke	2GC11	-	11	67	7	18	-	Formerly developed
Young Creek (Lake Erie Drainage)-								
Vittoria	-	2GC35	14	20	2	7	50	
Totals					134	369	592	

Table 8

2. Pollution

(a) General Effects

Pollution effects are of two kinds: those affecting public health and those which are not a hazard to human health but which are offensive to people or harmful to stock or to fish and other aquatic organisms. The first type can usually be measured by the concentration of an indicator organism (the bacillus E. coli.). The second type is measured in terms of poisonous compounds which may be introduced into the river and in terms of oxygen depletion and the oxygen demand (B.O.D.)*. Silting has additional effects. Shifting sand bottoms are virtual aquatic deserts.† Colloidal clay prevents light penetration and retards the growth of aquatic organisms, making the water unsightly and undesirable for swimming. Silt from land of good fertility may occasionally fertilize the water, producing an unsightly growth of algae. More often silt covers the normal bottom fauna and destroys the stream for fish.

The commonest type of pollution is that caused by the discharge of wastes containing dissolved or suspended organic compounds. Domestic sewage and most industrial wastes are predominantly of this type. Certain bacteria and other organisms cause the decomposition of these organic compounds by consuming the organic solids and combining them with oxygen. The resulting shortage of oxygen in the water is one of the chief symptoms of a polluted stream.

Aerobic decomposition of organic compounds in water, (i.e. in the presence of ample dissolved oxygen)

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* The B.O.D., or Biochemical Oxygen Demand, is a measure of the oxygen that will be demanded by the material in the course of its complete oxidation biochemically. It is determined wholly by the availability of the material as a bacterial food and by the amount of oxygen utilized by the bacteria during its oxidation.

† Tarswell, C.M. and Gaufin, A.R., "Some Important Biological Effects of Pollution Often Disregarded in Stream Surveys". Proceedings of the 8th Industrial Waste Conference, 1953, Purdue University, U.S.A.

finally results in the formation of compounds such as carbon dioxide, water, nitrates and sulphates.* Being comparatively stable, they exert no further demand for oxygen, produce no foul odours, and do not cause septic conditions in the water. They do, however, fertilize the water and stimulate the growth of plant and animal life in the stream. Dense growths of green algae are normally a sign that the stream is recovering from organic pollution.

In the absence of dissolved oxygen in the water "anaerobic decomposition" of organic wastes takes place. Oxygen is then consumed from the organic materials and compounds remain such as methane gas, hydrogen sulphide gas, ammonia and others having little or no oxygen. Many of these products have highly disagreeable odours typical of polluted waters. Sometimes the decomposition products are lethal to fish and other aquatic organisms, but more often these die from lack of oxygen.

Since the amount of oxygen water can dissolve is so small†, sewage treatment facilities should be designed to turn out an effluent that is already decomposed biologically, so that the stream's oxygen reserves will not be called upon to an appreciable degree for this purpose.

Apart from bacterial pollution the types and abundance of both plant and animal species in a stream provide an excellent measure of the condition of the water. At the one extreme severely-polluted waters may contain extensive growths of gray-brown fungi, vast numbers of scavenger types of bottom-feeding organisms, a great bacterial population (or a sterile condition), and little or no dissolved oxygen. At the other end of the scale clean waters will support green algae, insect larvae, snails, clams, game fish and other organisms requiring abundant oxygen.

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* Proper treatment of sewage wastes should include two phases, primary treatment (mechanical removal of most solids) and secondary treatment (digestion of the remainder by aerobic decomposition, as here described).

† Less than 20 parts of oxygen per million parts of water by weight.

The time and distance required for recovery of a polluted stream depend on many factors, such as the temperature and volume of flow of the water, the type of pollutant at the polluting effluent, the type of stream bed and types of obstructions such as dams.

A full report on pollution in the Big Creek Region would require that the following work be carried out:

(1) Bacterial plate counts at all points suspected of bacterial pollution, and at regular space intervals in the courses of the various streams elsewhere.

(2) Measurement of the oxygen content in bacterially polluted sections and where industrial wastes enter the streams, with additional measurements of the Biochemical Oxygen Demand below sources of industrial and bacterial pollution in order to estimate the rate of recovery of the streams.

(3) Measurement of the amount of silting and turbidity, and their effects on the life of the streams.

(4) Assessment of the present treatment plants, by relating the estimated minimum stream flow to the maximum flow of the effluent (provided that these can occur at the same time).

(5) The assessment of the present pollution sources, apart from municipal treatment plants.

(b) Conditions on the River Courses

The following report is based on observations made during a biological survey of all the waters of the Big Creek Region, in 1955, and also on more recent information from the Water Resources Commission of Ontario and from other sources. Neither bacterial tests nor tests of the oxygen content of the water were made during the biological survey. At the time of the survey pollution could not be considered a major problem in the Big Creek Region as a whole. However, three sections of the river courses did show serious pollution. Delhi, on Big Creek, provides primary and secondary treatment to its sewage and has one of the most efficient sewage treatment plants in the province. A station examined about 1½ miles below Delhi on the main stream showed a wide variety of fauna and no important indicators of pollution. The whole creek and its

tributaries appeared to be in exceptionally good condition apart from a road crossing a quarter of a mile south-west of New Durham. At this road crossing in North Norwich Township, there was considerable pollution from cattle. There is a chicken-killing plant at New Durham and it is important that wastes from this plant should not reach the creek, particularly since the stream is reduced to standing pools in dry summers and there would not be a satisfactory dilution. Clear Creek, in Houghton Township, and Dedrich Creek, in South Walsingham Township, were both in good condition when examined. Young Creek, in Charlotteville Township, was in excellent condition, but there was a dump of garbage and other debris at the road crossing immediately west of Walsh. It is possible that this dump might pollute the stream.

(1) The Lynn River

a Simcoe

When the 1955 biological survey was made, no pollution was observed at any of the 12 "reporter stations" on the Lynn River above Simcoe. At that time Simcoe's waste treatment consisted of an Imhoff tank and intermittent sand filters, built in 1914 and enlarged in 1928 and 1942. There were also other polluting effluents both above and below the treatment plant. The river itself was in a severely-polluted condition for several miles below Simcoe.

A new treatment plant using the activated sludge system was planned, and its construction approved, shortly before the Water Resources Commission took over the responsibility for pollution control in Ontario in 1956. The new plant is now in operation with a capacity of 1,000,000 gallons and should be amply sufficient for Simcoe's present size and population (8,005 as of 1957). Assuming a standard capacity of 100 gallons per head of population, and efficient operation, the plant would take care of a population of 9,000 or 10,000, plus a considerable amount of industrial waste depending on its quality.

The expected dilution of the wastes by the Lynn River must also be considered. There are no records available of the flow of the river above Simcoe. The best estimate, therefore, is calculated by deducing the probable minimum flow at Simcoe, in a given period, from the measured flow of an adjacent stream with similar characteristics.

Based on the flow of Big Creek, prorated on an aerial basis, and using the method of calculating the probability of the occurrence of seasonal water deficiencies which is described in Appendix "A", it is estimated that the flow of the Lynn River will not be less than 15-20 c.f.s. at Simcoe more thanonce in 5 years. The maximum flow of the effluent at Simcoe has been estimated by the Manager, Simcoe Public Utilities Commission, to be about 1,000 gallons per minute or about 2 c.f.s., and the normal daily summer maximum to be 1 c.f.s. The expected minimum dilution should therefore not be less that 7 to 1. This appears to be a satisfactory ratio.

It takes several weeks for a new activated sludge plant to settle down to stable operation, and at the time of this report (December 1957) this plant was not yet in its stable operating condition. The river was therefore still in a polluted condition.

Even when the new plant is operating at maximum efficiency, there will still be several sources of pollution which will remain to be dealt with. There appear to be two textile plants, whose effluents are still discharged directly into the river. At the Canadian Canners plant, the effluent from the tomato waste division goes into a storm sewer and directly into the river. This is a very important polluting effluent.

At the fruit preserving plant and jam factory, although the main effluent goes into the sanitary sewer, it appears that there may be still one pipe connected to the upper pond of the river. It also seems probable that part of the

effluent from the operations of galvanizing and plating in a coupling and fitting plant, north-west of the upper pond, is entering the pond without proper treatment.

There also remains one street with a few private homes whose sewers are still connected to the storm sewer and therefore pass directly into the river and not into the new treatment plant.

b Port Dover

While the problems of pollution at Port Dover are chiefly dealt with by septic tanks, there is now little doubt that there are a number of sanitary sewers which enter into the storm sewer and thus into the Lynn River without any treatment. There are also a canning plant and fish and chicken processing plants whose effluents pass directly into the river. The severe pollution at Port Dover is a serious deterrent to the attractions of Port Dover as a recreation centre.

(2) Nanticoke Creek

During the survey Nanticoke Creek was observed to be polluted, just above its mouth, by debris from a fish processing plant.

3. Flood Problems

Chapter 2 of this report gives an account of the flood history in the Big Creek Region Watershed. Unfortunately, missing records leave long periods during which no information regarding flooding is available.

The watershed is fortunate, however, in that its topographic and physical characteristics tend to prevent the serious floods which occur in most other watersheds. The area is mainly flat which prevents fast run-off. The soil is predominantly of a sandy texture which has high infiltration rates. The main watercourses are located in deep valleys which are high enough to contain most of the flood flows and narrow enough to prevent extensive development close to the

rivers. Past damage has been done mainly to riverside structures such as bridges, dams, mills, etc. Urban development has been largely on high ground although there are instances of where water has risen into built-up areas. In February of 1954 the Lynn River flooded some riverside homes and damaged culverts in the vicinity of Simcoe. Again in February of 1956 it flooded parts of Pond Street. In general, however, the flood problems are not considered to be serious. Some channel improvement works at Simcoe would improve the flow and reduce the occurrence of future flooding. The construction of controlled conservation storage dams would also aid in controlling the flood flows.

Ice jams can cause serious floods even when the river flow is below the considered flood level. Damage can occur at the mouth of the rivers when "ice shoves" occur. These are usually due to a combination of (1) a heavy ice sheet forming in quiet backwaters from the lake, preventing ice floes from the river passing out into the lake, or (2) ice floes from the lake piling up in the river mouth by strong on-shore winds coinciding with the river break-up.

In the case of the former, "ice channelling" through the heavy ice sheet prior to the river break-up offers some measure of relief and may prevent the formation of ice jams altogether. If the outlet is threatened by ice floes from the lake, a tug might be employed to keep the mouth open. It is understood that ice channelling has been resorted to in the past and it is strongly recommended that it be continued as required.

Ice barriers brought in from the lake by wind, and consolidated by freezing spray, at the present time can only be removed by blasting. Experiment with Thermite* and

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* Thermite is a trade name for a mixture of aluminum powder and a metallic oxide (usually iron) which develops a very intense heat when ignited.

coating the ice with a dark substance to increase the solar heat absorbtion, have been carried out. The former has not proved successful; in areas where large amounts of cinders are available the latter method provides an economical means of reducing the hazard.

Flood damage can be reduced by an early warning system which would warn the downstream areas of the impending flood. The establishment of such a system should be encouraged. Proper land use and good conservation practices in general will aid in reducing fast spring run-off and consequent floods. Care should be taken in the future that commercial and residential development does not extend into areas subject to flooding. Bridges and roadways constructed across valleys should be designed to handle the expected peak flows and offer as little obstruction as is economically possible.

4. Irrigation

Irrigation of tobacco is widespread throughout the area wherever soils of the Fox, Plainfield or Bookton sand types occur. The heaviest concentration is in the North Creek area where the percentage of farmers irrigating has risen from almost zero per cent in 1952 to over 60 per cent today. The rate of increase reached its peak in 1955, mainly due to the dry weather experienced during that year. Although there has only been a five per cent increase in the number of irrigation systems during the past two years, it is significant that there has been a 20 per cent increase in water sources, as the farmers have gone ahead and dug ponds in anticipation of dry weather. Should a drought similar to that of 1955 be repeated, it is almost certain that the acres irrigated would exceed those of 1955.

At present, irrigation is limited mainly to tobacco. It is conceivable, however, that with the expected growth in population, farmers will find it economical to irrigate other crops such as vegetables, potatoes and pasture.

Today, only about 4,000 of the 14,000 acres in the North Creek watershed have been granted tobacco rights. In 1955, 1,752 acres were irrigated; that is, 12.48 per cent of the total acres in the watershed, or 44.83 per cent of the base tobacco acreage rights. (In 1957, the figures were 401 acres, or 2.87 per cent and 10.26 per cent respectively). With the advent of increased tobacco acreages and other crops being irrigated, it is easy to visualize an irrigated acreage of 3,500 acres or 25 per cent of the total acreage in 15 or 20 years hence. These figures apply to the North Creek watershed only and some consideration must be given to the irrigation potential of the other areas. Consideration must also be given to the future development and water demands of areas downstream and plans be made to ensure an adequate flow in the streams.

Since irrigation in the Big Creek Region is presently concentrated in the North Creek watershed, a detailed investigation was made of the water requirements and problems of that area.

Table 9 shows a summary of the 1955 and 1957 irrigation and water usage survey made on the North Creek watershed. The information and recommendations resulting from these surveys can also be applied to other areas within the Authority where similar conditions are possible in the future.

During the dry summer of 1955, a study was made of the flow in the various rivers of the Big Creek Region. It was found that where streams had their headwaters in sand plains, flow was maintained longer than those which rose in clay plains. Big Creek and its tributaries maintained a fairly steady flow in most cases. This was also partly true for the Lynn River. Both of these rivers lie in sand plains. Black Creek, on the other hand, was almost completely dry on September 14th. In this case, the stream flows through a clay plain.

TABLE 9

IRRIGATION AND WATER USAGE SURVEY 1955 & 1957

	ITEM	1955 Survey	per cent	1957 Survey	per cent
Frequency of Tobacco growers and irrigators - by farms	Total number of Farms	118	100.00	134	100.00
	Total growing Tobacco	106	89.92	111	82.82
	Total not growing Tobacco	12	10.18	23	17.18
	Total irrigating	66	55.92	68	50.70
	Total not irrigating	52	44.08	66	49.30
Frequency of irrigation by acres	Total Acreage	12,101	100.00	13,971	100.00
	Total Acres Tobacco Rights	3,730	30.82	3,908	27.97
	Total irrigated Acres per cent of Total	1,670	13.83	401	2.87
	Total irrigated Acres per cent of Rights	1,670	44.88	401	10.26

Acres irrigated	Year	Acres	% of Total	% of Rights
From 1955 to 1957	1955	1,752	12.48	44.83
(Figures obtained from 1957 Survey)	1956	1,547	11.08	39.59
	1957	401	2.87	10.26

Note: The above figures were obtained by 2 farm to farm surveys. Differences in the number of farms and total acreages are due to the differences in the extent of the surveys and also the changing ownership of land.

This phenomenon is due to the sandy soils being able to absorb more precipitation and thereby reduce the surface run-off. This builds up the ground water storage which feeds the streams during periods of no precipitation. The clay soils, on the other hand, have low infiltration rates and consequently less available ground water. From this, it can be seen that during drought periods, stream flow relies on the amount of water stored in the aquifer. This flow is required to dilute effluent from sewage disposal works and provide water for municipal, livestock and wildlife needs. Should the flow be too little or the stream dry up completely, serious consequences can result.

These facts must be kept in mind when considering possible water sources for irrigation needs. During 1955 there were a number of disputes arising from the use of water from streams. Some farmers dammed up the rivers or diverted the flow into by-pass ponds, thereby preventing flow to downstream users. Quite often a group of farmers would pump heavily from the same stream reducing downstream flow, and in some cases cut it off completely. Fortunately, only 24.7 per cent of the irrigators in the North Creek area pumped water from streams in 1955. The majority drew water from groundwater fed ponds (67.9 per cent). Other sources were wells, by-pass and run-off ponds. In 1957 the number of ground-water fed ponds had increased to 71.13 per cent with stream sources dropping to 14.43 per cent. From this, it can be assumed that the farmers are resorting to the more reliable dug-out pond. In actual numbers, there were 55 ground-water fed ponds and 20 stream sources in 1955. This had changed to 69 and 14 respectively in 1957. These figures can be found in Tables 10 and 11. It should also be noted that in 1955 only 10 per cent of the water sources were considered inadequate, whereas in 1957 the figure was 4.12 per cent. However, 14.42 per cent of the sources in the latter case have not been "tested", since

TABLE 10

1955 SURVEY - IRRIGATION WATER SOURCES

1. Distribution of the Various Types of Sources

Source	No.	Per Cent of Total	Per Cent of Ponds
TOTAL NUMBER OF PONDS	59	72.8	100.0
Ground-Water fed By-Pass Surface Run-off	55 3 1	67.9 3.7 1.2	93.2 5.1 1.7
TOTAL NUMBER OF STREAMS	20	24.7	
TOTAL NUMBER OF WELLS	2	2.5	
TOTAL NUMBER OF SOURCES	81	100.0	

2. Adequacy

Source	Total	Very Good		Good		Fair		No Good	
		No.	%	No.	%	No.	%	No.	%
PONDS	59	6	10.18	38	64.40	5	8.47	10	16.95
STREAMS	20	-	-	19	95.00	1	5.00	-	-
WELLS	2	1	50.00	1	50.00	-	-	-	-
TOTAL	81	7	8.64	58	71.60	6	7.41	10	12.35

TABLE 11

1957 SURVEY - IRRIGATION WATER SOURCES

1. Distribution of the Various Types of Sources

Source	No.	Per Cent of Total	Per Cent of Ponds
TOTAL NUMBER OF PONDS	81	83.50	100.00
Ground-Water fed By-Pass Surface Run-Off	69 12 -	71.13 12.37 -	85.20 14.80 -
TOTAL NUMBER OF STREAMS	14	14.43	
TOTAL NUMBER OF WELLS	2	2.07	
TOTAL NUMBER OF SOURCES	97	100.00	

2. Adequacy of All Sources

Source	Total	Very Good		Good		Fair		No Good		Not Tested	
		No	%	No	%	No	%	No	%	No	%
PONDS	81	3	3.72	53	65.4	7	8.64	4	4.94	14	17.29
Ground-Water By-Pass	69 12	3 -	4.30 -	44 9	63.8 75.0	5 2	7.25 16.67	4 -	5.80 -	13 1	18.85 8.33
STREAMS	14	-	-	10	71.4	4	28.6	-	-	-	-
WELLS	2	1	50.0	1	50.0	-	-	-	-	-	-
TOTAL	97	4	4.12	64	66.0	11	11.34	4	4.12	14	14.42

3. Adequacy of the Three Branches of North Creek

Branch		Total	Good		Fair		Not Tested	
			No	%	No	%	No	%
By-Pass Pond	NORTH	6	4	66.66	1	16.66	1	16.66
	MIDDLE	6	5	83.40	1	16.60	-	-
	SOUTH	-	-	-	-	-	-	-
Streams	NORTH	8	6	75.00	2	25.00	-	-
	MIDDLE	3	2	66.60	1	33.30	-	-
	SOUTH	3	2	66.60	1	33.30	-	-
TOTAL		26	19	73.10	6	23.06	1	3.84

the past two years have been wet years, and the ponds recently dug have not been pumped sufficiently to ascertain their adequacy.

Complaints were also heard during the summer of 1955 from people other than irrigators. Dairy farmers downstream were afraid that the stream would dry up and their livestock be left without water. Wildlife officials were worried about the consequences of low flows and heavy pollution on the fish and game populations. Some communities were worried about their domestic water supplies. The problem, therefore, is to determine the best method of providing irrigation needs and still maintain adequate flow in the rivers.

From our preliminary studies* it was seen that for the years from 1937 to 1956 inclusive, the moisture deficiency for the period from July 1 to August 15 varied from 1.35 inches to 4.46 inches with an average of 2.95 inches, Probability studies show that a moisture deficiency of 3.0 inches for the above period would occur 48.0 per cent of the time, and 4.0 inches about 11.9 per cent of the time. Should water be provided for a deficiency of 3.0 inches, a pond of $(\frac{3}{12} \times 32) = 8$ acre feet would have to be provided for each 32 acres of tobacco irrigated. Allowing for evaporation and seepage losses, 2.52 inches could be available for irrigation on July 15. Assuming a dry growing period and allowing for evaporation and seepage, there could be one inch of irrigation about July 15 and 1.52 - (0.14 evaporation) = 1.38 inches for one or two applications at about August 1, which is believed to be none too much.

In 1955, Hisey and Barrington, Consulting Engineers, were engaged to investigate the irrigation water supply problem, and in their report they recommended that the necessary water be provided by means of (a) dug-out ponds lined

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* See Appendix "A". Irrigation Water Requirements.

with Bentonite which would be filled during the spring run-off period when there was a surplus flow in the streams, (b) construction of small temporary dams across small tributaries and drainage ditches, and, (c) construction of one or more larger dams on the main streams.

Since many of the dug-out ponds in the area go down into the ground water the lining was recommended to, firstly, permit the storing of water above ground-water level and thus increase the capacity of the ponds and, secondly, to prevent the use of ground water for irrigation.

In addition, the possibility of providing a storage pond on each farm which would be filled from one large storage concentration on the main branch of North Creek was investigated. This system required long pipe lines, large pumping units, and the cost was prohibitive.

Furthermore later studies and tests with pond linings indicated that this could not be done economically and therefore the use of lined dug-out ponds for storage purposes was not practical.

The preceding schemes were based on the premise that it is unwise to draw water from the ground water storage. The ground water feeds the streams during the dry season and by using this water for irrigation, the water table is progressively lowered until eventually the flow to the streams is reduced or cut off completely. It was for this reason that the preceding schemes suggested lining the ponds with impervious Bentonite which would prevent the ground water from seeping into the ponds.

Although this school of thought is correct, it is not necessarily critical for the North Creek region. Dean C. Muchel* states: "To conserve ground water does not mean to hoard it or to stop using it. It means proper use within the

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* Pumping ground water so as to avoid overdraft. U.S.D.A. Yearbook, Water, 1955.

limitations of the known supply and its replenishment". Overdrafts or shortages of ground water have developed in areas where uncontrolled use has occurred. This has happened where there has been a rapid growth of industry or cities, or in the Western United States where pump irrigation has developed to vast proportions. These overdrafts occur when the removal of water exceeds the recharge or the safe yield of ground water.

The ground water storage is supplied from inflow from other underground sources and from the infiltration of precipitation. Outflow, on the other hand, consists of one or all of the following items: Evaporation and consumptive use from land of high water table, surface streams discharging out of the area and underflow. The water level of the underground storage depends on the seasonal changes in inflow and outflow. During dry periods the water table drops, only to be recharged during the wet periods.

When pumping from the ponds is started, it is accompanied by a drop in the water level. The drop increases the opportunity for recharge from influent streams, reduces the underground outflow and the evapo-transpiration from uneconomic plants and wet lands. It increases the absorbtive capacity of the soil thereby enabling better penetration of the rain falling on the soil surface during the wet periods. In this stage of development, the use of ground water functions as a conservation measure by converting uneconomical losses to beneficial uses. In this respect, a ground-water reservoir is not unlike a surface reservoir. It can be said that a reservoir that is maintained full or nearly full at all times is not being used to the greatest advantage. Because of this, a falling water table during dry periods should not necessarily be viewed with alarm. It is the water stored during the wet period which is being used and in so doing the storage capacity is being increased for the wet periods that follow. On the other hand, a falling or even static water table during wet periods

indicates that the reservoir is not being fully replenished. This is a serious condition since it indicates an overdraft.

The disputes and cessation of flow which occurred in the North Creek watershed during 1955 were not caused by a lowering of the water table to a point where the underground water ceased flowing to the stream. The real trouble lay in the indiscriminate pumping directly from the streams by farms along their banks. Proof that no serious damage was done to the ground water storage lies in the fact that during the springs of both 1956 and 1957 the water table rose to within a few feet of the soil surface. Even as late as September of 1957, a few pools of water were observed in fields in some areas of the watershed, indicating a drainage problem. Some of these fields had been idle the whole summer due to the high water table but it must be remembered that 1957 was considered a wet year.

It should also be noted at this point that the rate of flow of the ground water is generally considered to be very slow. This means that any local serious overdraft or drop in the water table would be felt at the streams at a period much later than when the actual withdrawal was made. This is especially true in the North Creek watershed where ponds which could affect the flow of North Creek lie some distance from the actual stream. In 1955 some streams dried up during the 5- or 6-weeks drought period when pumping was occurring. Had an overdraft occurred from ground-water ponds it would not have been felt at this time, but rather at a later period, at which time it probably would have not been critical to the stream flow, since the drought had been broken and the stream flow increased by local precipitation.

It is evident, then, that streams which dried up during the irrigation period of 1955 did so because of one or both of the following two reasons: (a) extreme pumping directly from the streams, (b) the streams passing through an

aquifer with low storage capacity. (The latter case is typified by Black Creek which almost dried up completely. This river lies in a clay belt, away from the tobacco lands). It is felt that at present the amount of water removed from the aquifer for irrigation is not large enough, and the period of pumping not long enough to have a significant effect on the ground water storage when compared to the total annual recharge.

In view of the preceding discussion, the use of ground-water fed ponds is encouraged. However, observations should be kept of the ground water levels and test wells, with automatic or manual recording devices established to observe and record the daily and seasonal water level fluctuations at various points throughout the North Creek watershed. These recordings only become significant when a sufficient number of years of data has been obtained to detect any serious deviations from the normal fluctuations. Although it is felt that at present the amount of water removed from the ground storage is not large enough to cause any alarm, it must also be stated that this condition could very easily change in the years to come. Sound planning advises, therefore, that a number of observation wells be established now in order to provide the engineers in the future with a reliable and accurate history of the movement of the water in the aquifer. It is important that expert advice be obtained in the selection of the location of these wells.

There are a number of farmers whose ponds are not yielding sufficient water to allow continuous pumping. This condition is due to one or more of the following reasons: (1) insufficient water in the aquifer, (2) incorrect pond construction, (3) incorrect pond location, (4) the farmer expecting too much. The last condition is worth discussing. Quite a number of tobacco farmers try to get as much water on their land as soon as possible. Consequently, they operate high capacity pumps which soon pump their source dry. There

is a supposedly true story which typifies this point. In making an irrigation survey of the area, the investigator asked whether the owner had irrigated and, if so, how much water had been applied. "Why sure!" came the answer, "this year I irrigated it real good. Why I had 6 inches of mud all over the field at one point". Although it is hoped that this is the exception rather than the rule, it is felt that more irrigation "know-how" is needed among the farmers.

During the irrigation "boom years" of 1952 to 1955, many unscrupulous pond diggers invaded the area from all parts of Ontario. It has been said that "any fellow owning a dragline was out there digging holes". Consequently, many ponds were badly constructed and poorly located, which has resulted in many "enlargings", "rediggings" and digging of "second" ponds in the past two years. Thus a second point arises. It is recommended that some expert person or persons be available to advise in the future on the construction of ponds.

The problems of the aquifer not yielding sufficient water, or the water table being too deep to permit the use of dug-out ponds are probably the most serious. Farms located on the river banks are confronted with these problems since the river valleys vary from 40 to 50 feet in depth, the water table is drawn down to a depth far below that practicable for a pond. Consequently the farmer draws water directly from the stream which creates the problems mentioned earlier. The logical solution to this problem and the future water demands for the area, lies in the construction of a dam, or series of dams, on North Creek. This would raise the water table along the river and allow farmers to pump directly from the reservoir. It would also provide adequate storage to ensure a reliable stream flow and meet the growing domestic needs for Delhi and other communities. There would also be adequate storage to provide at least eight acre feet of water to all the farms in

Two pumps drawing water directly from a stream to irrigate tobacco.

A typical dug-out irrigation pond in the Delhi area.
Note the pump in the background.

A poorly constructed run-off pond. This should be improved by an adequate spillway, fencing to keep out cattle and a drinking trough placed outside the fence.

the watershed should the growth of irrigation ever reach the proportions which would cause a serious overdraft of the ground water storage. The schemes examined are outlined in Chapter 5, "Available Conservation Storage".

A preliminary estimate of the cost of the large dam as outlined in Scheme "A" would be $528,200 if clay is available for the construction of the earth fill. If it isn't, then a steel sheet piling cut-off wall would have to be placed in the centre of the dam which would raise the cost to $646,800. The unit cost of this dam would be $252 per acre foot and $307 per acre foot respectively. These figures, along with those for Scheme "B" are shown in Table (12).

Recent investigations have brought to light a third possible dam site on the North Creek where the valley narrows just below the confluence of the North and South Branches. A dam here would flood both the North and South Branch valleys giving, it is hoped, a lower unit cost. Before any final decisions are made on either of the North Creek schemes or the Lehman Dam, it is felt that this site should be investigated.

Finally, it is desirable that a sense of co-operation be developed among users of the stream flow. In many instances in the past it has been obvious that the selfish and indiscriminate use of the river water has robbed or denied water to downstream users. If such a spirit of co-operation is impossible to attain then it is recommended that the powers granted by The Conservation Authorities Act be used to ensure equal and fair use of the stream flow.

<u>Sand Points</u>

Sand points have been used in rural areas for many years as a means of obtaining a domestic water supply from the soil. Where there is a high water table, farmers have been known to drive a point into the ground to a depth of 6 to 10 feet and obtain an adequate supply.

TABLE 12

PRELIMINARY COST ESTIMATES FOR NORTH CREEK DAMS

1. Assuming no clay available

Scheme	Dam	Storage Ac.Ft.	Area Acres	Total Cost $	Unit Cost $ per Ac.Ft.
A	Lower	2,100	160	646,807	308
B	Lower	596	54	316,075	531
B	Upper	280	50	165,312	590
B	Upper plus Lower	876	104	481,387	550

2. Assuming clay is available.

Scheme	Dam	Storage Ac.Ft.	Area Acres	Total Cost $	Unit Cost $ per Ac.Ft.
A	Lower	2,100	160	528,187	252
B	Lower	596	54	277,597	466
B	Upper	280	50	145,489	520
B	Upper plus Lower	876	104	423,086	483

PRELIMINARY COST ESTIMATES FOR THE LEHMAN DAM

Scheme	Dam	Storage Ac.Ft.	Area Acres	Total Cost $	Unit Cost $ per Ac.Ft.
A	Dam alone	54.3	14	140,700	2,595
B	Dam plus Bridge	54.3	14	161,750	2,980

Scheme A - 57-foot Dam at Lower Site
Scheme B - 42-foot Dam at Lower Site in conjunction with 25-foot Dam at Upper Site

In recent years, this principle has been used for irrigation water sources. Larger diameter points are put down in batteries of four or more with their outlets manifolded together at a central point where the pumping unit is located. A number of such units do exist in the North Creek watershed and from all reports have proved to be successful.

The source of water is still the ground-water storage which places it in the same category as the dug-out pond. There are some advantages of this system, however, which should be mentioned. Firstly, the evaporation losses which occur from farm ponds are eliminated. Secondly, the concentration of withdrawal can be spread over a larger area. Thirdly, valuable crop land need not be permanently taken out of production, since the laterals running from the vertical points to the pump could be placed deep enough below the soil surface to allow cultivation over them.

In areas where the land is not needed, the laterals are placed on the ground surface.

It is necessary, however, that expert supervision be obtained in the placing of these systems. It is recommended that only one point be driven first and then test-pumped to determine whether the aquifer will provide the required volume.

CHAPTER 5

AVAILABLE CONSERVATION STORAGE

1. General

Detailed topographic maps of the Big Creek Region were examined for suitable reservoir sites. Altogether, 21 sites were selected and examined in the field, of which twelve appeared to be suitable for reservoirs. Of these, three were selected for more detailed study which included surveying and preparing contour maps.

The selection of these three sites was based on one prime factor, namely, the need for a storage reservoir to compensate for the water being used to irrigate the tobacco lands in the North Creek area. This is essential for the maintenance of stream flow for downstream uses such as domestic and industrial water supply, dilution of sewage effluent, livestock requirements, etc. (This problem of streams running dry due to excessive pumping for irrigation, was experienced during the dry summer of 1955). Other considerations were flood control, recreation, wildlife and low storage costs.

With the construction of the recommended dams, the present problems will be overcome. However, it is necessary at this point to give some consideration to the future development of the region.

There has been a rapid growth of population in Ontario during the past few years and it seems unlikely that this trend will be altered considerably. Along with this has come much industrial development which is taking out of production many acres of valuable agricultural land. There is no reason why the Big Creek Region should not share in this development provided sufficient water is available to meet the consequent demands. These two factors, namely, greater population and industrial development, and the reduction of crop producing acreages are bound to affect the existing agricultural practices. Where at present only tobacco is

considered sufficiently profitable to warrant intensive farming and irrigation, it is inevitable that other specialized crops will be required as this development takes place. This will bring even more acres under irrigation thereby increasing the demand for water.

It is difficult to visualize the exact degree of development within the next 25 years, or even the next 10 years, but it is necessary however, to make provisions now to meet the increasing demand for water. It is not suggested that all the dams be built at the present time, but rather that the Authority acquire the necessary land while land values are reasonable. As the area develops, the demands for land by industry, golf clubs, residential areas or by individuals, will send land values upwards as has happened in other industrialized areas in Southern Ontario. Should this happen, the cost of acquiring the necessary lands for the development of reservoirs would be exorbitant and even prohibitive. By acquiring the land now at a low cost the dams could be built as the demand for water warrants them. In the meantime, this land could be rented or turned into a recreational area thereby creating a source of income for the Authority.

Besides the purchase of land, other costs are numerous and varied. The major expense is in the dam itself, the cost of which varies with the height and length of the structure and the size of spillway required to pass the peak flood flows without endangering the structure. The spillway section involves expensive reinforced concrete works and in some cases steel sluice gates. Other costs are re-routing roads and railroads which would be flooded; replacement of bridges; clearing the flooded area; building fences, etc. Unfortunately, the valleys in the North Creek area are narrow and the stream gradients are steep. These factors do not lend themselves to low-cost storage, but the benefits to be derived from the reservoirs in the future will far outweigh the initial costs.

Locations of all the reservoir sites investigated are shown on the plan of the watershed, Figure 1.

2. Recommended Reservoir Sites

(a) North Creek Reservoirs

Since the North Creek presents the most urgent problem of a water shortage due to irrigation during dry summers, suitable storage basin locations in this area were investigated. Two sites were selected; one running between Lots 42 and 43 in Concession I NTR of Middleton Township, and the other in Lot 42 of Concession II NTR. (The former will be referred to as the Lower site, and the latter as the Upper site).

Two possible schemes are proposed. Scheme A would involve building one large dam to an elevation of 760 feet at the lower site. Scheme B would require two dams being built; the lower to an elevation of 745 feet and the upper to the 760-foot elevation.

(1) Scheme A - consists of a single dam 57 feet high and 400 feet long at the lower site. This would raise the water level to the 755-foot elevation eleminating the upper damsite which would be flooded to a depth of 20 feet. The reservoir would extend back 2.2 miles from the dam and provide a total of 2,100 acre feet of storage with a surface area of 160 acres. The buildings in the north half of Lot 42, Concession I NTR would have to be removed, and a 1,000-foot stretch of road in Lot 42 between Concessions I NTR and II NTR would be flooded.

The contour plans of the reservoir sites and the storage and area curves for these schemes are shown in Figure 6. The estimated cost of Scheme A, assuming that suitable impervious material for the core-wall is at hand, is $528,187.

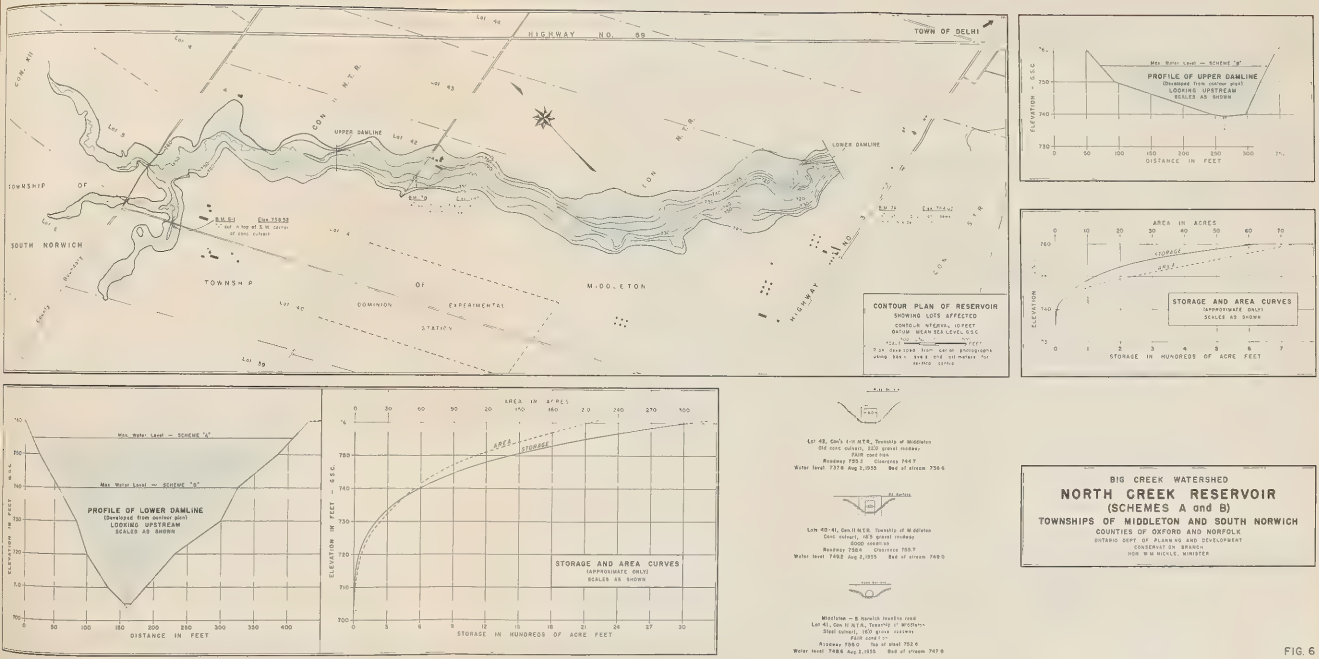

HIGHWAY NO. 59
TOWN OF DELHI
TOWNSHIP OF SOUTH NORWICH
TOWNSHIP OF MIDDLETON
DOMINION EXPERIMENTAL STATION
UPPER DAMLINE
LOWER DAMLINE
CONTOUR PLAN OF RESERVOIR
SHOWING LOTS AFFECTED
CONTOUR INTERVAL 10 FEET
DATUM MEAN SEA LEVEL G.S.C.
PROFILE OF UPPER DAMLINE
(Developed from contour plan)
LOOKING UPSTREAM
SCALES AS SHOWN
Max. Water Level — SCHEME "B"
ELEVATION - G.S.C.
DISTANCE IN FEET
STORAGE AND AREA CURVES
(APPROXIMATE ONLY)
SCALES AS SHOWN
AREA IN ACRES
STORAGE IN HUNDREDS OF ACRE FEET
PROFILE OF LOWER DAMLINE
(Developed from contour plan)
LOOKING UPSTREAM
SCALES AS SHOWN
Max. Water Level — SCHEME "A"
Max. Water Level — SCHEME "B"
ELEVATION IN FEET - G.S.C.
Lot 42, Con's I-II N.T.R., Township of Middleton
Old conc. culvert, 22.0 gravel roadway
FAIR condition
Roadway 755.2 Clearance 744.7
Water level 737.8 Aug 2,1955 Bed of stream 736.6
Lots 40-41, Con.II N.T.R. Township of Middleton
Conc. culvert, 18.5 gravel roadway
GOOD condition
Roadway 758.4 Clearance 755.7
Water level 749.2 Aug 2,1955 Bed of stream 749.0
Middleton — S. Norwich townline road
Lot 41, Con. II N.T.R., Township of Middleton
Steel culvert, 16.0 gravel roadway
FAIR condition
Roadway 756.0 Top of steel 752.6
Water level 748.6 Aug. 2,1955 Bed of stream 747.8
BIG CREEK WATERSHED
NORTH CREEK RESERVOIR
(SCHEMES A and B)
TOWNSHIPS OF MIDDLETON AND SOUTH NORWICH
COUNTIES OF OXFORD AND NORFOLK
ONTARIO DEPT. OF PLANNING AND DEVELOPMENT
CONSERVATION BRANCH
HON. W.M. NICKLE, MINISTER

FIG. 6

(2) Scheme B

The Lower site is located about 600 feet north of Highway No.3 where the top of the valley narrows to about 500 feet. An earth dam with concrete spillway placed at this site would be 315 feet long and 42 feet high above the stream bed which has an elevation of 703 feet. The reservoir would extend 1.5 miles upstream and have an average width of 400 feet giving a surface area of 54 acres and a storage capacity of 596 acre feet.

The only building affected is located in the north-east quarter of Lot 42, Concession I NTR. Although it will not be flooded, it is probable that the high water line will be fairly close to the building.

The concrete culvert in Lot 42, Concessions I-II NTR should be of adequate size; however, it appears to be in only fair condition and may have to be replaced.

The valley is at present heavily wooded with scrub and a few good elm and pine stands.

The Upper Site is located in Lot 42, Concession II NTR. This dam would be 295 feet long with crest being 25 feet above the stream bed elevation of 735 feet. A 5-foot freeboard would be provided making the spillway elevation 755 feet. It would be similar to the lower dam in construction. The reservoir would extend 0.8 miles upstream with an average width of 350 feet. It would have a water surface area of 50 acres and a storage capacity of 280 acre feet.

Although the reservoir would not flood any buildings or valuable crop land, it would necessitate the raising of two roads, viz., the South Norwich townline road in Lot 41, Concession II NTR, Middleton Township, and the road between Lots 40 amd 41 of the same concession. These works would be approximately 300 feet in length. The valleys are well wooded and would require clearing.

The two dams would provide a total storage capacity of 876 acre feet at an estimated cost of $423,086. If suitable impervious core-material is not readily available the cost would be about $481,387. The soil in the vicinity of these two sites is believed to be of a light sandy texture and soil borings would be required to determine the type of construction for dams at these sites. There is a clay deposit east of Delhi which could be used as a source for core material, or a watertight cut-off wall of steel sheet piling could be constructed. The economics involved in these two types of cpnstruction is summarized in Table 12.

(b) Delhi

A third reservoir site was surveyed just north of the town of Delhi on Big Creek. The damline is located on the lot line between Lots 23 and 24 of Concession X in Windham Township. The dam would have earth-fill embankments with a concrete spillway fitted with steel gates. The crest would be 35 feet above the stream bed allowing for a 5-foot freeboard. This would give a water level elevation of 725 feet. The structure would be 450 feet in length. The reservoir would extend 2.5 miles upstream with an average width of 460 feet; a total surface area of 182 acres and a storage capacity of 1,405 acre feet.

The valley is densely wooded with underbrush, poplars, alders and some merchantable cedar. The valley floor is wet and swampy with a number of single track roads in poor condition passing through it. Should the dam be built, the road dividing Concessions IX and X of Windham Township would be flooded to a depth of 8 feet for a distance of almost 2,000 feet (where it passes through Lot 23) and consequently would have to be abandoned. Another road will have to be raised for a distance of about 200 feet in Lot 22, Concession IX. The timber bridge at this point is in good condition and should have about five feet clearance when flooded to the 725-foot elevation. A third crossing on the line between

Concessions VIII and IX in Lot 22, consists of a concrete and steel bridge in good condition. The reservoir would narrow at this point thereby preventing any flooding of the road.

The contour plan of this reservoir is shown in Figure 7 and the dam and reservoir data for all the above reservoirs are tabulated in Table 13A.

3. Other Reservoir Sites

(a) Glenshee

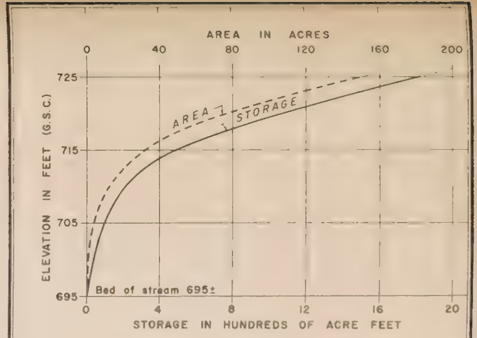
This site is located on Trout Creek in Lot 1, Concession X of Charlotteville Township. A detailed survey was not made; however, from the topographic maps, it is estimated that a dam 24 feet high would form a reservoir 1.6 miles long covering 77 acres, with a storage capacity of 608 acre feet.

The damsite is heavily wooded and the pond area is overgrown with weeds and bush. Further upstream is located a corrugated iron arch-type culvert under a sand road. This culvert replaced an old timber dam and bridge but the original pond area is silted up to the level of the old spillway. The new dam would flood over these structures.

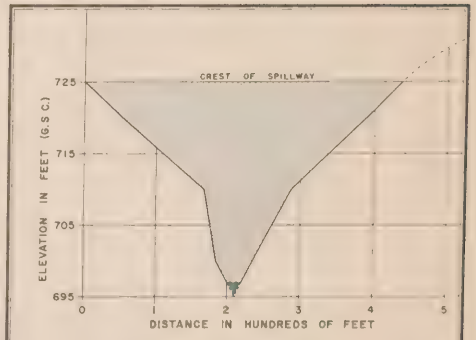
(b) Langton

This site is located on the Venison Creek in Lot 6, Concession XIII of North Walsingham Township. From topographic maps, it is estimated that a 30-foot wall would store 1,056 acre feet over an area of 211 acres. The reservoir would be a relatively short wide body of water with the dam wall being 475 feet long.

The valley has steep banks which are well wooded and will require clearing. An old dam is located further upstream at the first road crossing. Nearby are two good farm buildings and a concrete-block house. Should the dam be built, its height could be such that these buildings would not be flooded unless necessary.



STORAGE AND AREA CURVES
(APPROXIMATE ONLY)
SCALES AS SHOWN



PROFILE OF DAMLINE
(Developed from contour plan)
LOOKING UPSTREAM
SCALES AS SHOWN

BIG CREEK WATERSHED

DELHI RESERVOIR

TOWNSHIP OF WINDHAM

COUNTY OF NORFOLK

ONTARIO DEPT OF PLANNING AND DEVELOPMENT
CONSERVATION BRANCH
HON. W. M. NICKLE, MINISTER

FIG. 7

(c) La Salette

An estimated 3,264 acre feet of storage could be obtained by building a 23-foot high dam on Big Creek, just north of the Michigan Central Railway tracks in Lots 20 and 21, of Concession VIII, in Windham Township. The dam would be about 660 feet long and would create a reservoir 1.8 miles long with an average width of 680 feet.

Suitable impervious fill material would probably have to be brought in from some other area since the soil at the damsite is of a sandy texture. The valley is well wooded with heavy bush and some merchantable timber. There are two road crossings further up the river which would be flooded should the reservoir be raised to the 750-foot elevation. Since no detailed survey has been made of the site, it cannot be said here whether or not new bridges would have to be built. In all probability, the existing structures will suffice; however, the road approaches would have to be raised.

Farmers are pumping water from Big Creek at this location to irrigate their tobacco crops. By constructing this dam, an adequate supply will be stored and stream flow maintained.

(d) Marston

This site is located on Venison Creek, in Lot 3, just north of the road separating Concessions VIII and IX in North Walsingham Township. The reservoir would lie about one mile west of the village of Marston.

The valley at the site has steep high banks, and is suitable for a 30-foot dam, 425 feet long. Suitable clay material is available. The reservoir would be 2.0 miles long with an average width of 635 feet, giving a total storage of 3,280 acre feet covering 192 acres.

The valley is well wooded with dense undergrowth. There are three bridges in the area, one of which would definitely be flooded by the proposed reservoir. The valleys at these points are V-shaped with steep wooded banks.

(e) New Durham

This damsite is located just east of the village of New Durham in Lots 21 and 22, Concession IX, in Burford Township. A small dam, 9 feet high, would create a 58-acre pond storing 96 acre feet of water.

The area consists mainly of pasture land on a fairly heavy clay soil. There is no tobacco being grown in the immediate vicinity but water for irrigating other cash crops may be required in the near future.

(f) Oriel

This location is suitable for a small dam 13 feet high and 790 feet long. The site is about 1½ miles south of Oriel in Lot 11, Concession VIII in East Oxford Township and has a drainage area of 3.6 square miles.

The dam would create a lake covering 77 acres and storing 256 acre feet. The area at present is cultivated and planted to tobacco right to the water's edge. Since this site is in the headwaters of Big Creek, there was no defined stream course where the observation was made. There were a number of standing pools of clear, cold water, however; some containing trout fingerlings.

(g) Venison

This site lies in the tobacco-growing district to the south-west of the village of Walsingham. It is located on Venison Creek, about one mile upstream from its confluence with Big Creek.

A 25-foot dam, 581 feet long, built just west of the road in Lot 7, Concession V in South Walsingham Township, would create a 96-acre lake storing 800 acre feet of water. The valley is broad and flat and contains some fair pasture land. The area is fairly well wooded with scrub brush and a few large maples, elms and poplars, with scattered pine, spruce and cedars along the slopes. The stream follows a well-defined course with no signs of serious flooding.

The reservoir would back up to two bridges, which would have to be investigated for possible flooding.

The first is a timber bridge with 5.9 feet clearance and the second is a steel structure with 13.2 feet clearance.

(h) Wyecombe

This location is on a tributary of Big Creek, just north of the road in Lot 21, Concession XI, in North Walsingham Township.

A 40-foot wall, 425 feet long would flood 154 acres with 2,240 acre feet of water. The reservoir would back up to the roads to the north and to the west of the dam-site and possibly would flood the existing 30-inch diameter corrugated culvert. The roads themselves, however, would not be flooded since they have 33 feet or more fill above the existing water level. Since the road embankment has steep slopes, reinforcing or extra fill would have to be placed to bring the slopes to the correct angles so as to prevent eroding.

The valley is V-shaped and is densely wooded with good elm, maple and birch.

(i) Woodhouse

This site is located on a tributary of Black Creek in Lot 9 of Concession IV, Woodhouse Township.

A total of 211 acres would be flooded by a dam 32 feet high and 425 feet long, giving a storage capacity of 2,376 acre feet. With a small drainage area of 2.9 square miles, this reservoir would probably not fill to capacity each year but a reserve water storage could be built up during wet years for use in times of drought.

No evidence of tobacco being grown in the vicinity was observed. The valley divides into two broad, flat fingers. The area is mainly used as pasture and is scattered with elms and willows. At the time of the observations there was no flow; however, there were indications of flooding.

(j) Marburg

This site is located on a tributary of Black Creek in Lots 16 and 17, Concession IV, Woodhouse Township.

The topography is suitable for a dam 27 feet high and 540 feet long, which would impound 2,460 acre feet of water covering an area of 269 acres.

The reservoir would be divided into two arms, each extending back over two miles from the dam.

With a small drainage area of 6 square miles this reservoir would probably not fill to capacity each year.

(k) Tyrrell

Located just north of the Marburg site in Lot 16, Concession XII, Townsend Township. A dam 22 feet high by 685 feet long could be constructed at this point to impound 1,630 acre feet of water.

The reservoir would flood about 230 acres of land and interfere with one roadway. The drainage area above this site is only 2.6 square miles and would not fill to capacity during years of low spring run-off. However, being at the headwaters this site is ideally situated for a summer flow reservoir.

(l) Rockford

This site is located in Lots 18 and 19, Concession XIII, Townsend Township, about one mile south-east of the Tyrrell site. This is one of the best sites in the watershed from the amount of storage capacity available, but being located near the headwaters with a limited drainage area of only five square miles, there would not be sufficient run-off every year to fill it.

A dam 36 feet high and 1,060 feet long could be constructed to impound 6,860 acre feet of water. The reservoir would be 2.5 miles long with a surface area of 480 acres. Sections of three separate roads would be flooded but with such a large potential storage capacity the height of the dam could be reduced to minimize this damage and still provide sufficient storage to serve the needs of the area.

It is not suggested that any of the reservoirs in this group be built at this time but the above sites are mentioned in order that the Authority may be aware of their potential should some less important development, which would interfere with the use of these areas for water storage purposes in the future, be under consideration.

All of the above data were obtained from topographical sheets and a brief visual examination of the areas. The data for the dams and reservoirs are shown in Table 13B.

4. Lehman Dam

Since the town of Delhi at present relies on North Creek for its domestic water supply, some concern has arisen over the low stream flows during the dry summer periods when heavy irrigation pumping occurs. This has led to the investigation of new water supplies, one of which is the possibility of restoring the old Lehman Dam on North Creek immediately south and west of the town limits. This site is adjacent to the existing water filtration and pumping plant of the Public Utilities Commission of the town of Delhi.

A firm of Consulting Engineers were engaged to investigate replacing the Lehman Dam and their report has recently been submitted (December 1957) to the Authority.

The report outlines two schemes, "A" and "B". Scheme "A" would be the construction of a new dam only, whereas Scheme "B" would combine the new dam with a new bridge as part of the gravel road which crosses North Creek just downstream from the damsite. In both schemes the storage required was based on the estimated population in 1975 being 5,400 (1957 - 3,018), and calculated for the irrigation pariods of thirty and forty days, assuming that during this time the flow in North Creek is sufficient to compensate for the net evaporation loss from the reservoir. The daily consumption per capita is estimated at 100 gallons. The storage required for the thirty-day period in 1975 would be 10,950,000 gallons

while 14,600,000 gallons are required for the forty-day period. The reservoir is designed to store the latter figure which is equivalent to 54.3 acre feet.

The total cost for Scheme "A" is estimated at $140,700 and for Scheme "B" $161,750. Included in these figures are $5,700 for the filtration plant intakes. The unit cost for Scheme "A" is $2,590/acre foot and for Scheme "B" $2,975/acre foot.

It is suggested that a comparison of these costs be made with those estimated for the North Creek reservoirs which are found in Table 12 in the Irrigation section of Chapter 4 of this report.

TABLE 13A

DAM AND RESERVOIR DATA FOR RECOMMENDED SITES

Name of Reservoir	Total Drainage Area Square Miles	D A M			R E S E R V O I R			
		Height above Bed of Stream Feet	Length in Feet	Spillway Capacity not less than c.f.s.*	Length in Miles	Average Width Feet	Surface Area Max.W.L. Acres	Storage Capacity at Max.W.L. Allowing 5' Freeboard
NORTH CR. (Scheme A)	12.72	57	400	3,210	2.2	400	160	2,100
" " (Scheme B) Upper Site	10.14	25	295	2,580	0.8	350	50	280
" " (Scheme B) Lower Site	12.72	42	315	3,210	1.5	400	54	596
DELHI	116.19	35	450	26,220	2.5	460	182	1,504

* Spillway capacity for maximum probable flow as determined in Chapter 3 - Hydrology.

CHAPTER 6

COMMUNITY PONDS

The advantages of community ponds are twofold. Firstly, they conserve water which is a necessary attribute in any conservation program. Secondly, they provide a place of recreation for the members of the rural communities. Unlike farm ponds, they do not provide facilities for a single family but rather are developed to accommodate the needs of large groups of people. Besides storing water and providing fire protection, these ponds are used for swimming, boating, fishing, skating and picnics.

Several factors should be kept in mind when investigating the possibilities of developing a community pond. First of all, the pond should be able to accomodate the expected number of people using it. It should be easily accessible and close to the community. There should be sufficient area for parking and picnicking. Adequate facilities for sanitation, change rooms and possibly confectionery should be available. The area should be free of hazards and safe for swimming, boating and skating.

Some of the above facilities were provided to a degree in earlier days by the community millponds. For generations these were the gathering places for small boys who used to swim and fish in the summertime and skate in the winter. To-day, however, the mills have been converted to electric power thereby eliminating the use of the power obtained from the water of the pond. This has resulted in the dams falling into disuse until to-day; in most cases, they have deteriorated to a condition beyond repair. Many have been washed out completely and the ponds have disappeared. However, since the millponds to a large extent fulfil the requirements as mentioned earlier, they should be given first consideration as sites for possible community ponds.

In addition, many of these old buildings have much historical value attached to them which could be incorporated into the scheme of things in the form of a museum or points of interest.

Very few of the 60 or more millsites existing in 1865 remain to-day. In order to restore most of the ponds, new dams would have to be built. One pond which is still in good condition is the Backus Pond located north of Port Rowan. The original mill still exists and the pond and surrounding area have already been acquired for development as a public recreational area.

Unfortunately, the topography of the region does not lend itself ideally towards good pond sites. The valleys are too deep and the stream gradient too steep. This prohibits low-cost ponds with sufficient water surface area for recreational purposes. The region has been inspected for a number of community pond sites well distributed throughout the region. Those found suitable appear on the map in Figure 8. The following list gives the exact location and comments on the various sites, which are classified into three groups:-

P = possible pond site
E = existing pond
N = natural pond

<u>BURFORD TOWNSHIP</u>

P-1 <u>NEW DURHAM - Lot 22, Con. IX</u>

Possible site north of the road below fork. Pond area approximately 10 acres; dam 250' long.

P-2 <u>NEW DURHAM - Lot 20, Conc. VIII</u>

Old millsite ½ mile below P-1. All traces have disappeared and area is all open pasture.

The Backus Pond in the Backus Conservation area.

A view of an abandoned gravel pit which could be developed into a community pond.

The washed-out mill dam one mile north of Lynedoch, which could be restored to make a community pond.

P-3 KELVIN - Lot 10, Conc. XIV

Old mill site ¼ mile north of road, east from Kelvin. Dam disappeared, and some silting of the old bed. Pond area about 20 acres. Dam 300' long.

WINDHAM TOWNSHIP

E-4 LAKE HUNGER - Lot 17, Conc. III

Only large, natural pond on the watershed. Area 25 acres. East end is being privately developed, but there is a possibility of development on the west and wooded north shores.

E-5 TEETERVILLE - Lot 14, Conc. V

Existing mill pond of 20 acres. Best shore is occupied by a farm but steep wooded east bank and old mill buildings have possibilities for development.

P-6 BRANDY CREEK - Lot 20, Conc. VIII

Site for larger dam at abandoned railroad crossing; 30-acre pond in wooded valley with access by paved road at upper end.

E-7 BRANDY CREEK - Lot 20, Conc. IX

Very small (2-3 acre) pond possible here on minor tributary. Lies off road behind farm.

P-8 LYNVILLE EAST - Lot 4 & 5, Conc. X

A dam 200' long would produce a fair-sized pond in pleasant surroundings.

MIDDLETON TOWNSHIP

E-9 DELHI - Lot 46, Conc. II

Pond about half a mile long. Good playground development at upper end by local service club. Good canoeing area. Excellent possibilities.

P-10 DELHI,W., Lot 41, Conc. II

Five-acre pond site 1½ miles west of Delhi. Good access to head of pond, treed banks and woodlot below damsite. Dam would be about 200' long.

P-11 DELHI,W., Lot 38, Conc. II

Five-acre pond site 2 miles west of Delhi, just south of No. 3 Highway. Good wooded area below dam.

P-12 LYNEDOCH - Lot 42, Conc. IV

The old mill site has disappeared. A short dam would provide a four-acre pond with picnic grounds at head of pond.

WALSINGHAM TOWNSHIP

P-13 LYNEDOCH,W., Lot 23, Conc. XIV

Narrow, treed valley. Good damsite at paved road. Pond would cover three or four acres.

P-14 LANGTON - Lot 10, Conc. XI

Old pond, traces of 250'dam remains. Convenient access - little shade.

P-15 GLENSHEE - Lot 21, Conc. XI

A fair damsite for small pond at road between Concessions X and XI. Five-acre pond with good access.

P-16 SILVER HILL - Lot 22, Conc. IX

A dam 300' long would create a three- or four-acre pond in a narrow, well-shaded valley. Access by secondary road.

E-17 WALSINGHAM - Lot 13, Conc. VI

Existing two-acre pond in village of Walsingham. Good access on surfaced road. Well-shaded banks.

P-18 WALSINGHAM, Lot 12, Conc. V.

Possible site on main stream. Good access. Long spillway would prove expensive.

P-19 GLEN MEYER - Lot 8, Conc. XIV

Good damsite for pond of 10 acres. Near road with good shores.

P-20 MARSTON - Lot 4, Conc. VIII

Excellent site on secondary road. Short dam, 10-acre pond with well-shaded banks.

P-21 VENISON CREEK, Lot 7, Conc.V

15-acre pond possible with 250' dam. Good access through old road allowance. Well-wooded shores.

P-22 VENISON CREEK - Lot 8, Conc, IV

Alternate site to P-20 below road. Not as attractive and longer dam required.

CHARLOTTEVILLE TOWNSHIP

P-23 SIMCOE, W., - Lots 21 & 22, Conc. X

Broad flat site requiring 350' dam. Excellent accessibility from Highway No. 3 and secondary road. Suitable picnic and playing areas.

E-24 VITTORIA - Lot 22, Conc. III

Good existing mill-pond.

TOWNSEND TOWNSHIP

P-25 NANTICOKE CREEK - Lots 22 & 23, Conc. XI

A flat plain having a rock shelf on south-west side of road. Small natural pools already existing. Could be developed.

P-26 TYRRELL, E., - Lots 20 & 21, Conc. XII

Attractive site. Temporary dam 50' wide and 4' high would create a long narrow pond. Plenty of picnic and hiking area. Three miles east of Tyrrell.

P-27 TYRRELL, S., - Lot 13, Conc. XIV

Broad, flat site requiring 300-400' dam. Pond approximately 25 acres. Land cleared.

WALPOLE TOWNSHIP

P-28 NANTICOKE, N., - Lot 6, Conc. II & III

Broad flat plain under pasture. No really suitable damsite. A nearby quarry, however, has a number of large ponds which could be developed along with the attractive meandering river. One mile north of Nanticoke.

WOODHOUSE TOWNSHIP

P-29 BLACK CREEK - Lots 19 & 20, Conc. IV & V

Very pleasant surroundings. Well wooded. Temporary dam or weir required. About 1,000 yards or more of stream could be developed. Suitable picnic and parking areas.

P-30 SIMCOE, E., - Lot 7, Conc. V

Two miles east and one mile south of Simcoe. Good reservoir site. Banks 15-20' high: dam 200' long. Pleasant surroundings, well treed.

COMMUNITY PONDS

LEGEND

NATURAL POND SITES (N)

EXISTING POND SITES (E)

POSSIBLE POND SITES (P)

FIG 8

CHAPTER 7

FIELD SURVEYS

All surveys made during this study were of a preliminary nature.

Twenty-one locations were selected from topographic maps as possible sites for reservoirs. These were examined in greater detail and three were selected to be surveyed for the preparation of contour plans by stereo-projection from aerial photographs. These were named North Creek Scheme "A"; the Upper and Lower North Creek, Scheme "B"; and the Delhi Reservoirs. The contour plan of the Delhi reservoir was drawn at a 400' to 1" scale with 10' contour intervals from field survey data and aerial photographs. The horizontal scale of the photographs was accurately determined by check-chaining stretches of roads or fence lines which could be readily identified on the photographs and comparing these distances with the measured distance on the photograph.

The vertical control for the mapping was done by establishing Bench Marks at the upper and lower ends of the reservoir by means of checked lines of levels. The intermediate spot elevations were obtained by using Wallace and Tiernan type, F A. 176 precise altimeters. The storage capacity of the Delhi reservoir measured from the plans prepared by the above method, is believed to be correct within five per cent.

The contour plans for the North Creek Reservoirs were prepared from aerial photographs using a Fairchild stereo-comparagraph. Bench Marks at the upper and lower ends of the sites were established and a line of levels run around the perimeter of the reservoir areas. Points at convenient intervals were identified and their elevations recorded. These points were used as the starting points for lines of altimeter readings which formed a cross-section pattern over the valley. Elevations of prominent points identified on the photographs were again recorded. The contour plans were then completed by using a stereo-

comparagraph to tie in the contour lines between the recorded elevations. The scale in this case was 500' to 1" with ten-foot contour intervals. The horizontal scale was determined in the same manner as the Delhi reservoir. The storage capacities determined are believed to be correct within 20 per cent which is acceptable for this preliminary survey.

Levels run in this survey commenced at G.S.C. Bench Mark No.1705 in Woodstock and were carried through to all the reservoir sites. Altogether, 47 Bench Marks were established along approximately 20 miles of base levels. These Bench Marks will expedite any further work in the area particularly should it be decided to proceed with the construction of a reservoir.

CHAPTER 8

SUMMARY

This report gives an account of the physical characteristics of the watershed and the problems arising from man's demands and uses of the natural resources as applied to water.

Chapter one outlines the topography of the region and provides statistics as to the size and shape of the area, type of soils, length and gradients of streams and the municipalities in the area.

Chapter two presents an interesting review of extracts from known records of former floods. These start with a surveyor's diary as far back as 1796, and continue with later diaries and newspaper reports until the present day.

The hydrology of the area is carefully examined in Chapter three. This includes a summary of the available precipitation and stream flow records. From the Big Creek area records, it is shown that the maximum flows occur during March and April with a maximum mean daily flow of 1,630 c.f.s. occurring in March 1956. The actual peak was probably as high as 2,360 c.f.s. The low flows occur during August to December, inclusive, with a minimum of 104 c.f.s. occurring on Big Creek at Port Rowan in December 1947. The Chapter also deals with unit hydrographs and design storms; the latter to be used in the designing of the proposed storage reservoirs.

Chapter four discusses the water problems arising in the area, and points out that although pollution is not considered a major problem in the watershed, there are certain trouble spots which require attention. Simcoe has boosted its sewage treatment capacity in recent years; however, the effluent being discharged from two textile plants and a preserving plant and jam factory is seriously polluting the Lynn River. Other sources of pollution are

a galvanizing and plating plant, and private homes which pass their sewage into storm sewers which empty into the river. The problems of pollution at Port Dover are mainly attributed to sanitary sewers being connected to the storm sewers, canning plants and chicken and fish processing plants.

The problem of flooding is not considered serious, and while no specific flood prevention works have been investigated, it is recommended that an early warning system be developed, correct conservation practices be carried out, and construction on the flood plains be prohibited.

A major problem in the watershed, which has received widespread attention,is that of irrigation. Two surveys were made, one in 1955 and the second in 1957. Statistics resulting from these investigations appear in table form. These show a trend towards more irrigation with the main source of water being from farm ponds. It is felt that the serious condition of streams drying up during the dry summer of 1955 were due primarily to the direct pumping from the streams. The pumping of the ground water storage from dug-out ponds is not considered dangerous at the present time; however, it is recommended that observation wells be established so that a reliable account can be kept of the fluctuating water table. It is also recommended that the Authority endeavour to improve the irrigation "know-how" of the tobacco farmers; advise on the location and construction of farm ponds; give serious consideration to the construction of a dam on North Creek; and discourage and, if necessary, prevent the pumping of water directly from the streams. The possibility of using sand-points as a means of obtaining a water supply from the aquifer is discussed.

A table showing the comparative preliminary construction costs and unit costs of the construction of the North Creek and Lehman dams is presented for consideration.

In Chapter five, a general discussion outlining the advantages and necessity for the prompt investigation of storage reservoirs precedes the actual description of the various reservoir sites. Altogether, 14 sites were investigated, and the data applying to the drainage areas, the dimensions of the dams, storage capacities and surface areas, etc., appear in table form.

In addition to the large reservoirs, community ponds which would serve either for recreation or as a source of limited water supply for domestic use and fire protection, are also recommended. A discussion about the benefits of these ponds and a list of 28 locations is presented in Chapter six.

Finally, Chapter seven provides information about the methods used and tolerances attained during the actual field surveys. This information is of use to technical personnel who will be reading this report, and who require the necessary information regarding the accuracy and method of producing the maps and drawings found herein.

APPENDIX A

ESTIMATE OF IRRIGATION WATER REQUIREMENTS FOR TOBBACO CROPS IN THE DELHI AREA

Introduction

In order to assess reasonably the economic value of artificial storage of water for tobacco irrigation, it is necessary to know how frequently various amounts of water are required. The following Tables II and V give probabilities of requiring various amounts of irrigation water during the tobacco growing season. These were obtained by methods suggested by van Bavel (1) and Robertson (3).

1. Assumptions in Method

The following calculations of moisture deficiencies at Delhi have been made from available meteorological data by a daily moisture budget tabulation based on the following assumptions:

(1) A typical tobacco soil within the root zone of tobacco plants has a water storage capacity of one inch. (References 1 and 2)

(2) Weekly figures for potential evapotranspiration (P.E.) calculated from 15-year averages of temperature by the simplified Thornthwaite formula (P.E. = 0.1 (T-32)) are sufficiently accurate estimates of P.E. (Any errors introduced by this assumption would likely be small and self-compensating rather than cumulative.)

(3) The irrigation season for tobacco in the Delhi area is approximately June 1 to August 15.

(4) The general assumptions of the daily moisture budget method for computing water deficiencies are valid for tobacco crop irrigation calculations. (Reference 3)

2. Results

The tabulations were made for each of the 20 years of record (1937-56). Monthly and seasonal totals are given in Table I.

TABLE I

Moisture Deficiencies (inches) - Delhi

Year	June	July	Aug. 1-15	Total
1937	.30	1.95	1.04	3.29
38	2.59	1.77	0	4.36
39	2.35	2.84	.17	5.36
40	1.30	2.96	.93	5.19
41	1.62	1.72	1.16	4.50
42	1.93	1.32	1.08	4.33
43	.02	1.23	.30	1.55
44	1.13	3.23	1.11	5.47
45	.22	1.40	1.33	2.95
46	1.67	3.19	1.27	6.13
47	1.39	1.47	1.75	4.61
48	1.46	2.79	1.55	5.80
49	2.77	1.71	1.62	5.10
50	2.20	.36	.99	3.55
51	.83	.91	1.43	3.22
52	3.36	2.26	.04	5.66
53	1.94	2.68	.79	5.41
54	1.97	2.99	.62	5.58
55	2.41	2.04	.43	4.88
56	2.89	2.08	.64	5.61

Average seasonal deficiency = 4.68"

Standard deviation σ = 1.19"

3. Probability and Frequency Analysis

If the total seasonal deficiency figures can be assumed to form a normal distribution, the probability of the occurrence of seasonal deficiencies exceeding various amounts can be obtained from normal curve tables.

Results of the probability determinations are as in Table II.

TABLE II

Probability Table for June 1 - Aug. 15
Moisture Deficits

Deficit Amount	% Probability of Deficit Greater than Amount
5.00"	39.4
5.50"	24.5
6.00"	13.4
6.50"	6.3

In other words, approximately once every four years the moisture deficiency will be 5½" or greater, and once every 16 years the moisture deficiency will be 6½" or greater.

4. Evaluation of Results

These figures are, of course, higher than would be obtained by the Thornthwaite technique used on a monthly basis, assuming a soil moisture storage of 4 inches. Their relation to present and future irrigation water requirements depends largely on the methods that are used by the farmers to determine dates and amounts of water to apply to the crop. Of 5 irrigation scheduling methods used in tobacco growing, 2 would be likely to give close correspondence of water use to the above figures. These are the moisture budget method (ref.3) and the weekly schedule method. (The latter goes by the rule that irrigation water plus rain must equal one inch per week during the season June 1 to August 15. This implies that average P.E. during this season is 1" per week. Our figures show 1" for June and August and 1.1" for July, which is close correspondence.)

Figures, on water quantities actually used for irrigation of tobacco, were available only for the Delhi experimental farm and for the years 1954, 1955 and 1956. Table I shows fairly high deficiencies for the month of June in each of these 3 years, yet from the Delhi figures, no June

irrigation was undertaken in any of these years. However, if the calculated figures for June deficiencies are ignored, the computed water requirements and the actual water used are in good agreement as shown in Table III.

TABLE III

Calculated vs. Actual Irrigation Amounts

Year	Calculated Def. July 1-Aug. 15	Irrigation Amount Applied July 1 - August 15
1954	3.61	3.6
1955	2.47	2.7
1956	2.72	2.7

This suggests that either (a) favourable growth conditions during June may require that the soil be frequently dry to force the plants to root deeply or (b) that additional benefits would be obtained by irrigating during June.

If the former (a) is the case, then the total irrigation requirements should be obtained from the moisture deficiencies for the period July 1 to August 15 only. The totals for these periods are as in Table IV.

TABLE IV

Moisture Deficits
July 1 - August 15

Year	Deficit (ins.)	Year	Deficit (ins.)	Year	Deficit (ins.)
1937	2.99	1944	4.34	1951	2.34
1938	1.77	1945	2.73	1952	2.30
1939	3.01	1946	4.46	1953	3.47
1940	3.89	1947	3.22	1954	3.61
1941	2.88	1948	4.34	1955	2.47
1942	2.40	1949	3.33	1956	2.72
1943	1.53	1950	1.35		

Average deficit = 2.96"
Standard deviation σ = .88"

Assuming normal distribution this table gives deficiency probabilities as in Table V.

TABLE V

Probability Table for July 1 - August 15
Moisture Deficits

Deficit Greater Than	% Probability
3.00"	48.0
3.50"	27.1
4.00"	11.9
4.50"	4.0

This implies then that about once every 4 years a deficit greater than 3.5" will occur, about once every 8 years a deficit greater than 4" and once every 25 years a deficit greater than 4.5".

References:

1) van Bavel, C.H.M., "A Drought Criterion and Its Application in Evaluating Drought Incidence and Hazard". Agronomy Journal, Vol. 45, No. 4, April 1953, pp. 167-171.

2) Walker, E.K., "Recommended Practices for Flue-Cured Tobacco Irrigation". Proceedings of First Ontario Irrigation Conference, Feb. 1956, pp. 14-15.

3) Robertson, G.W., "Estimating Irrigation Water Requirement from Meteorological Data". Proc. of First Ontario Irrigation Conference, Feb. 1956, pp. 1-7.

ABBREVIATIONS, EQUIVALENTS AND DEFINITIONS

Abbreviations

ac. ft.	is the abbreviation for acre foot which is the equivalent to 43,560 cubic feet and is the quantity of water required to cover one acre to a depth of one foot.
c.s.m.	is the abbreviation for cubic feet per second per square mile and is the average number of cubic feet of water flowing per second from each square mile of drainage area.
c.f.s.	is the abbreviation for cubic feet per second and is the unit generally used to express discharge or the rate of flow.
G.S.C.	is the abbreviation for Geodetic Survey of Canada which refers to the official datum of elevations above mean sea level as established by the Geodetic Survey of Canada.
M.P.N. or m.p.n.	most probable number
ML or ml.	millilitre
P.P.B. or p.p.b.	parts per billion
P.P.M. or p.p.m.	parts per million
PH or ph	value measure of acidity or alkalinity

Equivalents

1 c.f.s.	= 6.25 imperial gallons per second
1 c.f.s. for 1 day	= 1.98347 acre feet or approximately 2 acre feet
1 c.f.s. for 1 year	= 724 acre feet
1 ac. ft.	= 271,472 imperial gallons

1,000,000 imperial gallons per day = 1.86 c.f.s.

Definitions

AQUIFER is a water-bearing stratum or formation.

BOOST STORAGE is the storage required to increase the head of water over the discharge tubes in order that they may be able to discharge the required flow.

CHANNEL CAPACITY or "IN-BANK" FLOW is the maximum flow which is contained within the river banks and does not overflow the adjacent low lands.

CHANNEL CAPACITY STORAGE is the volume of water that must be impounded in order that the stream flow will not exceed the channel capacity flow or stage.

CONSERVATION STORAGE is that volume of water remaining in a reservoir which may be used to augment the low flows and is equivalent to the maximum storage capacity of the reservoir less the dead storage, evaporation and ice losses and the space reserved for flash floods.

DAM is a structure in and across a river valley to impoun(control and otherwise regulate the river flow.

DEAD STORAGE is the amount of water kept in a reservoir at all times for the purpose of protecting the artificial and natural water seals at the base of the dam.

DISCHARGE TUBE or CONDUIT is an opening through the base of the spillway to provide means for discharging water when the water level of the reservoir is below the spillway level.

FLOOD is an overflow or inundation coming from a river or other body of water.

FLOOD CONTROL is the prevention of flooding by controlling the high water stages by means of storage reservoirs, dikes, diversions or channel improvement such as widening, deepening and straightening.

FLOOD CONTROL STORAGE is the total volume of water that must be impounded during a given flood in order that the stream flow will not exceed the channel capacity flow or stage and is equal to the sum of the channel capacity, dead, boost and operational storages.

FLOOD CREST is the maximum height or stage that the flood waters reach during any one flood period.

FLOOD HYDROGRAPH - a hydrograph which covers only the flood period or time interval during which the river flow is above the flood stage.

FLOOD RATIO is the rate of peak flow to the average flow for the flood period.

FLOOD STAGE is an arbitrary flow stage which varies from place to place and from season to season and is that flow or water level at which the water threatens to do damage.

FREEBOARD is the vertical distance between the maximum permissible water level and the top of the dam or dikes.

GROUND WATER is the portion of the subterranean water which occurs in the zone of saturation.

GROUND WATER STORAGE or RESERVOIR is a term used interchangeably with aquifer.

HYDRAULICS as applied to conservation deals with the measurement and control of run-off from river drainage basins.

HYDROGRAPH is a plot of flow against time and is a correct expression of the detailed run-off of a stream resulting from all the varying physical conditions which have occurred on the drainage area above the gauging station previous to the time which it represents.

HYDROLOGY is the science which deals with the occurrence and distribution of water in its various forms over and within the earth's surface. As applied to conservation it deals more specifically with that portion of the hydrologic cycle from precipitation to re-evaporation or return of the water to the seas and embodies the meteorological phenomena which influence the behaviour of the waters during this phase of the cycle

OPERATIONAL STORAGE is additional storage that is required to provide a safety factor to enable the controller to regulate the discharge from a dam so as not to exceed the channel capacity flow or stage.

RATE OF RUN-OFF is the rate at which water drains from an area. Usually expressed in cubic feet per second (c.f.s.).

RATE OF RUN-OFF PER SQUARE MILE is the average number of cubic feet per second of water flowing from each square mile of area drained (c.f.s./sq. mi. or c.s.m.).

RESERVOIR is the body of water created by the construction of a dam.

RESERVOIR CAPACITY is the maximum amount of water that may be contained within the reservoir without exceeding the maximum permissible water level. Usually expressed in acre feet.

RUN-OFF is the amount of water which reaches the open stream channels and may be broadly defined as the excess of precipitation over evaporation, transpiration and deep-seepage.

RUN-OFF DEPTH IN INCHES is the depth to which the area would be covered if all the water flowing from it were conserved and uniformly distributed over the surface.

SPILLWAY is that part of a dam over or through which the water is discharged.

SPILLWAY CAPACITY is the maximum amount of water that may be discharged over the spillway without exceeding the maximum permissible water level in the reservoir.

STREAM GAUGE is a measuring device used to determine the elevation of the water surface at selected points - usually a graduated rod fixed in an upright position and set to a known elevation from which the gauge readings are obtained by direct observation. Automatic type gauge is a mechanically operated recording instrument which gives a continuous record of water surface elevations.

WATER or CLIMATIC YEAR is a 12-month period from October 1 to September 30. The water year was found to be a more convenient form than the calendar year for the purpose of stream flow studies as it groups together those months in which the water losses due to evaporation and vegetation demands are at a minimum (October - March) and those during which the losses are high (April - September).

WATER TABLE is the upper surface of the zone of saturation.

ZONE OF SATURATION is the portion of the earth which is saturated with water.